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PRESENT AND PROPOSED ACTIVITIES OF THE FRANKLIN INSTITUTE *

A REPORT TO THE MEMBERSHIP BY

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Secretary of the Institute.

THE last few years have been years of vigorous life and activity in the Institute, and have witnessed growth and development which promise much for greater usefulness of the Institute to the city, and for enhanced reputation for this old society. Unfortunately, some of our members report that, to their regret, they have not been cognizant of these facts; they have expressed the wish that they might have an opportunity to learn in person of the plans and purposes about which now they read only in the papers. Apparently we are not good advertisers, and have been so much occupied with the plans themselves that we have had little time and energy to tell about them.

In preparing the programme of meetings and lectures for the year, the Secretary felt that the lecture season could not be inaugurated better than by a comprehensive report concerning the state of the Institute to the members of it. Thereby should come sympathetic understanding, warmer interest and more active support. So he has given himself the privilege, which is a pleasure, of addressing you tonight

* Presented at the Stated Meeting of the Institute held Wednesday, October 17, 1928.

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on the "Present and Proposed Activities of The Franklin Institute." He will find satisfaction and encouragement if the activities of the Institute, and especially our new branches of work, described in this report to the membership, shall meet with your approval.

Laments have been uttered by some of our older members that our meetings have lost something of interest through their increased efficiency and the opinion has been expressed that they would regain their former quality if there could be more genuine discussion. Tonight offers the opportunity for such a revival. You are sincerely invited—"if you see a head" which you don't like, to "hit it." It is genuinely wished that if you do not approve of what is being done or is being planned, you will say what you think now, or at some early opportunity. You will observe that we do not use the ministerial admonition, "Let him now speak or else hereafter forever hold his peace."

It has been, I believe, a long-time practice of the Institute to honor the speaker of the evening by having him meet at dinner, in advance of his talk, some of his Philadelphia friends, some of the outstanding figures of Philadelphia life, and a few of the members of the Institute. There seemed to be no need for such a dinner tonight in honor of the speaker. A much more agreeable motive was suggested, that the dinner of this evening be made one of honor to all those members whose membership exceeded a certain minimum, but large, number of years. The suggestion was eagerly accepted. The problem then was to determine this *minimum* period of membership. Forty years was adopted tentatively for this number, and a census of our membership was taken to find how many guests could be invited under this limitation. To our great satisfaction, we found that no less than seventy-one members "had joined the Institute more than forty years ago." A dinner for such a number was more than we ventured to plan for. Consequently, we raised the limit to forty-five years and took a new census. It showed that of our membership, 31 had been members for forty-five or more years, so invitations were sent to all of these 31. Eight gave us the pleasure of attending the dinner in their honor, and have shown their interest by coming to this meeting tonight. The

speaker feels much complimented by the presence of these honored and youthful fathers of the Institute. Our presiding officer is one of the short-time members. He joined the Institute only a little more than forty-seven years ago and has been successfully active in all of the affairs of the Institute from that time to the present. One of the thirty-one has been uninterruptedly a member of The Franklin Institute for more than sixty-two years. Surely these figures which have been quoted constitute a superb record of loyal support.

I cannot forbear from referring to the saddest incident in the affairs of the Institute during the last year. One year ago we were meeting under the chairmanship of our honored President, Dr. W. C. L. Eglin. He appeared to be at the peak of his acknowledged powers—able, forceful, considerate, courageous. We naturally looked forward to years of successful effort with his powerful aid and encouragement. On February 7, last, he was taken from us by death; the Institute was lastingly bereaved by the loss of this man for whom we knew great respect, cordial admiration and warm affection. We mourn the taking off of a strong man and a gifted leader.

It is sometimes a good thing to be reminded of things. Tonight I wish to recall to you something that you all know already, the origin and the purposes of The Franklin Institute.

In 1823 and 1824, so the records tell us, two young men—W. H. Keating, subsequently Professor of Chemistry in the University of Pennsylvania, and Samuel Vaughan Merrick, later the first President of the Pennsylvania Railroad, were desirous of learning something of the applications of fundamental science in business and industry. They applied for membership in a society then existing and in which they believed they could readily learn what they wished to know. To their great indignation, probably to their surprise, they were refused admission. Then they did a sensible thing—they took counsel together and thought over the whole situation. They were young men of high standing, they were of the socially elect. Said they, "if *we* cannot find the opportunity to learn what we wish to know, what chance has the poor boy who has no friends? We will organize a society open to all men and women of intelligence, character and ambition who are interested in science."

This was the inception of The Franklin Institute. It was organized as a democracy in science whose purpose was "the promotion of the mechanic arts." It has remained true to that purpose to this day. With one exception, the activities assigned by the Founders are carried on today with vigor.

They started a library in the physical sciences and, after a few years began to collect patent literature. Today our library is the best library in the physical sciences in or about Philadelphia, and possesses the only great collection of patent literature to be found between New York and Washington. We are the official depository for the governments of the United States of America and Great Britain, and have their complete files, and have much patent literature from other foreign governments.

"The Fathers" started a journal for dissemination of scientific knowledge. That Journal of The Franklin Institute has appeared twelve times a year without interruption from 1825 to the present time. I know of no journal or magazine of its type which has anything like a comparable record of age and continuity. Our Journal has become an outstanding journal of physical science. Thanks to the publications of scientific papers from our research laboratories, the laboratories of the Bartol Research Foundation, the Journal will not fail to deserve an increasingly high reputation.

From the outset the authorities of the Institute have arranged for lectures before our members and their friends by the leading men of the world in their several fields of study. Much stimulation and much encouragement have resulted for the scientific workers of the city. A glance at the lecture programme which has been sent to you will convince you that a high standard of excellence has been maintained for these talks. Many of the scientific marvels of the world have been first publicly described in the Hall of The Franklin Institute. This practice has been continued. The brilliant Directory of Research of the Eastman Kodak Company has asked if he may present the first public description of the new method devised by the Eastman Kodak Company for taking motion pictures in the natural colors at a meeting of the Institute. This lecture and demonstration will be offered to us in this Hall next week.

During all of its history, the Institute has been greatly interested in inventions and has desired to encourage and to aid inventors. For the accomplishment of these purposes, the Institute now has eight medals which are awarded for discovery or invention in different fields only after careful investigation by committees of experts appointed from a group of sixty men who constitute our Committee on Science and the Arts. All of the medals which are awarded during the Institute year are now presented to their recipients on out last meeting day of the year in May, which is known as Medal Day. It seems to have become one of the interesting scientific events of Philadelphia.

These are the activities of the Institute which were initiated by our forbears which are carried on successfully, we hope, today. We are trying in every way to strengthen these lines of work so that they shall be of more value to our members and to Philadelphia.

One other activity which was started almost at the organization of the new society has been discontinued after ninety-nine years. Schools were conducted in the Institute in various branches of pure and applied science, physics, chemistry, mathematics, machine design, engineering drawing, architecture. Many of the leaders of Philadelphia life had their training in the schools held within these walls. The great Central High School of Philadelphia had its inception here and, for years, was known as the Franklin Institute High School.

But other institutions, of which Philadelphia is properly proud, came in and carried on the work admirably and sufficiently, so that The Franklin Institute could devote itself and its limited funds to work which others were not doing at all. The schools of the Institute were discontinued, wisely, I am sure, yet with regret, I feel equally sure.

We have not been content to carry on *only* along the old lines. We desire to open new roads to learning for our members and for the citizens of Philadelphia, especially for the children in the schools of the city. And we have opened a new agency for the advancement of human knowledge and have created a great tool to aid in man's conquest and domination of Nature—the laboratories of the Bartol Research Foundation.

May I take some of your time in order to describe somewhat in detail these new features of the work done here?

In the spring of 1926 our president, Dr. Eglin, suggested that a desirable addition for us would be a set of Christmas Week lectures for young people, similar to those which were first delivered by the great Faraday in the Royal Institution of Great Britain nearly a century ago and which have been given year after year, to the present time. This suggestion was adopted by the Board of Managers and the first course of lectures was arranged for. Those lectures were delivered by Professor R. W. Wood of Johns Hopkins University in the Christmas Week of 1926. An enthusiastic crowd of young people attended and were greatly rewarded by the absorbingly interesting lectures on "Recreations with Radiations" which they heard. The speaker cannot think of a more brilliant, a more attention-compelling, group of lectures than Professor Wood gave.

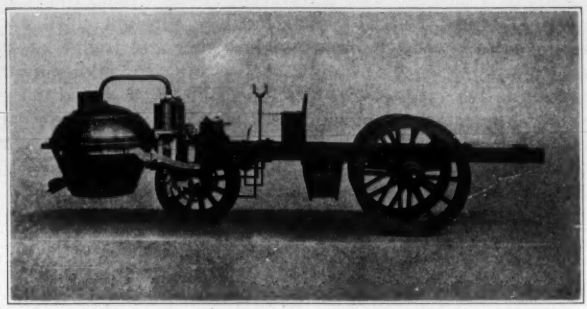
At the close of the course Mrs. James Mapes Dodge established the James Mapes Dodge Lecture Foundation as a memorial to her late husband, James Mapes Dodge, one of America's great inventors, the holder of some hundred and fifty letters patent from the United States alone, a long time member of The Franklin Institute, a member of its Board of Managers for years, a vice-president of the Institute at the time of his death—a congenial companion and a loving friend of young people. By means of this fine Foundation we are assured of our ability to carry on these Christmas Week Lectures for Young People at an almost nominal charge to the auditors and without drain upon the other resources of the Institute. In London, the Juvenile Lectures of the Royal Institution are attended by capacity audiences, including many of the leaders of thought and science of the kingdom. They are regarded as events of social importance and have been attended by the King and the Royal Family.

In 1927 our lecturer was Professor Wilder D. Bancroft of Cornell University, while for the lecture course of the approaching Christmas period we have been fortunate to secure Professor A. S. Eve of McGill University, Montreal, whose lectures will be on the topics, "Things that Spin," "Things that Swing," "Things that Wave." We are guaranteed a

wealth of striking experiments through all of these lectures and, I believe, an interesting trio of talks.

In 1918 Mr. Henry W. Bartol, a leader of industry in Philadelphia, bequeathed to The Franklin Institute his residual estate for the establishment and operation of a laboratory for research in the physical sciences and for the study and solution of problems of a scientific character.

FIG. 1.



The World's First Automobile.

You will see what freedom of action this gives to those directing the workers in the laboratory. After four years of litigation a settlement was arrived at by which the Institute received a sum which now amounts to one million, eight hundred thousand dollars, and which will eventually amount to at least two millions, four hundred thousand dollars, as endowment for the Bartol Laboratories.

During the years 1922–1925, four dwellings on the property of the Institute on North Nineteenth Street were remodeled and equipped for use as a physical laboratory. In the autumn of 1925 active research work was begun, the first Bartol Research Fellow, Dr. Arthur Bramley, was appointed, and an arrangement was entered into with Dr. Swann of Yale and Professor Adams of Princeton, to serve as an advisory committee to supervise research; a promising start was made

towards the fulfillment of the purposes of Mr. Bartol's handsome bequest.

In September, 1927, Dr. W. F. G. Swann, formerly Professor of Physics at the University of Minnesota, at Chicago University and at Yale University, at which place he was head of the Department of Physics, came to us as Director of the Bartol Research Foundation, in charge of the scientific work of the laboratories.

We have added other Fellows, all of high attainment and outstanding ability, who have come to us from Princeton, Yale, Harvard, Mt. Holyoke, Purdue, Virginia, until Dr. Swann is the head, the guide, philosopher and friend, of an enthusiastic scientific family, consisting, in addition to himself as Director, of eight or nine Fellows, a skilled glass-blower, three trained machinists, and the necessary clerical and other assistants. Dr. Swann has made of the Bartol Laboratories a hot-spot radiating scientific enthusiasm and sending out an ever-increasing stream of valuable contributions to scientific knowledge, accounts of work done and knowledge gained at our laboratories.

This work has gone on in spite of handicaps of a physical character. The houses on Nineteenth Street were not raised to be physical laboratories. They have about the physical steadiness of a teetering mosquito in a gale of wind. Every time an overladen truck dashes south through Nineteenth Street, or a P.R.T. trolley roars by, every piece of delicate apparatus indulges in a spell of St. Vitus' dance, and all measurements must be suspended. Because of these conditions the laboratories on Nineteenth Street are to be abandoned and the work now carried on in them is to be shifted to the Bartol Research Laboratories of The Franklin Institute now under construction on the campus of Swarthmore College. An agreement has been made with that College by which it leases to us a fine piece of ground for a nominal rental, on which we are building what promises to be an excellent laboratory. No other formal association is entered into. But the advantages are reciprocal. We obtain a fine site for our building in the atmosphere of a lovely, thriving college, with the cultural associations which go with life in such a community. Swarthmore gains the stimulating effect upon

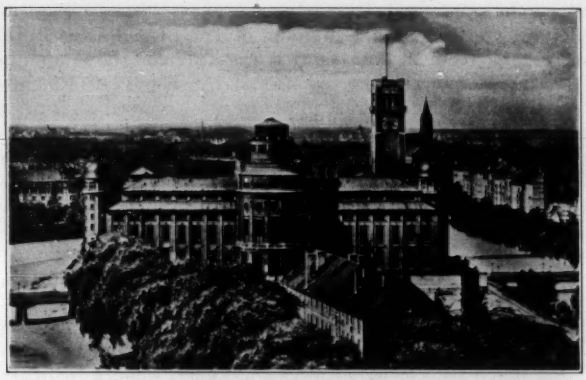
its students of the presence of a group of able young people carrying on researches of fundamental importance, and, perhaps also, the opportunity for some of its best students to assist in such researches. We hope to occupy the new laboratory about March first, after which we may confidently expect results which will bring reputation and satisfaction to Dr. Swann and his fellow-workers and honor to The Franklin Institute.

You will have seen in the daily papers during the last fifteen months, and especially since last May, frequent reference to the scientific museum of The Franklin Institute, and to an agreement between that Institute and the Benjamin Franklin Memorial, Inc., sponsored by The Poor Richard Club, by which such a great museum as is dreamed of, is to be made a possibility. The journalists of Philadelphia seem to have sensed accurately the importance of the project in hand and to have appreciated the value and importance to Philadelphia, and especially to the young folks of high school grade of this great new institution which we are eager to give to this city. These journalists have given us highly intelligent approval and support, without exception, and are giving us, and will give us, invaluable aid.

The Poor Richard Club, for a long time has had a great altruistic desire to do honor to its patron, Benjamin Franklin —that much adjectivized American. The Franklin Institute of the State of Pennsylvania has long sought to enlarge its contributions to the welfare of the youth of the country. During the last two years the Poor Richard Club has given much thought and study to the question of how they could best accomplish their purpose of doing honor to Franklin. That Club has organized the Benjamin Franklin Memorial, Inc., as its agency for fulfilling its desires. Under the leadership of Mr. Cyrus H. K. Curtis, and including in its membership the leaders of Philadelphia in finance, in engineering, in inventive industry, in good citizenship, the Benjamin Franklin Memorial, Inc., sponsored by the Poor Richard Club, has entered into an agreement with The Franklin Institute, in accordance with which they are to coöperate in bringing about the erection and equipment of a great, beautifying structure in a central section of the city,

preferably on the Parkway, which shall include a monumental architectural memorial to Benjamin Franklin, a collection portraying the graphic arts as they were when Franklin was an active printer in the Quaker City, and showing also their development to the present time, a great scientific and technological museum which shall rival the scientific museums of Europe, and the auditorium, library, offices and other

FIG. 2.



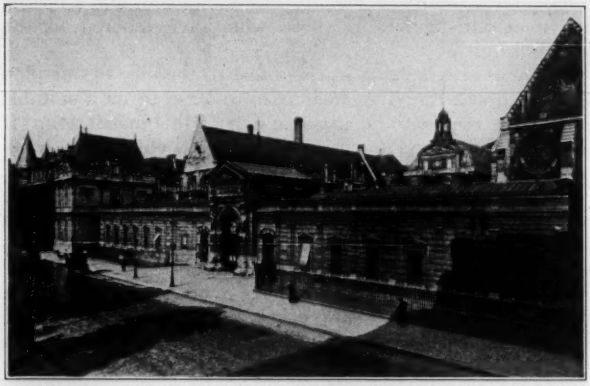
Deutsches Museum—Munich.

rooms demanded by the activities of The Franklin Institute.

The Benjamin Franklin Memorial, Inc., agrees to try to raise sufficient money, about four to four and a half million dollars, to erect the initial structure and to aid in its equipment. The Institute agrees to make available for endowment purposes that part of its fixed endowment which can be properly allocated to this project. That sum is now determined to be two millions, six hundred thousand dollars. The Institute will add to this endowment when possible to do so, and will aid in procuring funds from friends to whom an appeal may be effective because of their interest in The Franklin Institute rather than in the City of Philadelphia. The Institute will operate and administer the whole splendid structure for the benefit of the City of Philadelphia.

The ambition of the Benjamin Franklin Memorial, Inc., and of its parent organization, the Poor Richard Club, is solely to build what they regard as a proper memorial to Benjamin Franklin. They, however, recognize as clearly as any one, that Franklin would be the first to object to any memorial which was only ornamental and did not have as a large element in its character a quality of usefulness and applicability to ordinary affairs. They have therefore combined with The Franklin Institute to erect a great structure

FIG. 3.



La Conservatoire des Arts et Metiers—Paris.

which shall not only be a beautiful architectural memorial to Franklin, but shall also house a great new educational institution which shall carry on the work in which Benjamin Franklin was an epoch-making leader, and shall vitalize the teaching of physical science in this community. It is a pleasure to take this opportunity to pay sincere tribute to the Poor Richard Club and the Benjamin Franklin Memorial, Inc., for their altruism and public spirit as displayed in their present undertaking.

May we not justifiably feel that the whole structure with its living activities will be a superb memorial to that sage and

philosopher, Benjamin Franklin? The purpose and the work of the Institute have always been, perhaps, the most effective exemplification of the scientific principles of Franklin in that they have made a knowledge of science available to all men without regard to caste or state. In its new and enlarged sphere, which is to be made possible by the association of the Institute and the Benjamin Franklin Memorial, Inc., of the Poor Richard Club, the Institute will have as its fixed purpose to administer the Museum and Memorial so as to make it a worthy tribute to Franklin, a scientific shrine to which men will come for inspiration and learning, a noble addition to the architectural beauty of the city Franklin loved, and a lasting source of satisfaction to those who have labored for its accomplishment.

Because of our belief in the value to the city of our plan we have asked the city authorities to lease to us a suitable site for the erection and maintenance of this institution. If you believe in us and in our schemes, give us your support and your vocal approval.

We desire so greatly to have you understand what it is we are trying to build and why it is such an important thing for a city of two million people, that I ask you to bear with me while I outline our project and set forth our plans.

In the first place, there has come about a great change, a happy change, in our conception of the purpose and the character of a museum. Not so long since, a museum was merely a depository for the collections of a man with an acquisitive sense. All too often, it was only a junk heap, without much of designed arrangement, a more or less great collection of 'firsts' in the special field of interest. Only originals were tolerated—and copies, however perfect, were taboo. And all too often, the museum connoted death and inaction and lack of stimulus. Fortunately that conception of a museum has gone by the board. It is no longer primarily a home for collections. It is regarded as a great agency for education, for training, for enlightenment—and should be a dynamic adjunct to the teaching facilities of the community. These statements should be just as true—or more nearly wholly true—of a scientific museum as of an art museum, or of a commercial museum, or an historical museum. As a fact,

the accomplishments of science lend themselves with especial readiness to successful, inspiring use in such an institution as we have in mind.

You have seen in the great and beautiful Philadelphia Art Museum, at the top of the Parkway, a fine example of the possibilities of this new conception of a museum, as applied to a collection of works of art. The fine arts are there looked

FIG. 4.

Das Technische Museum—Vienna.

upon as unitary. They are to be grasped as an inter-related whole, and not as a mere congeries of more or less disparate units. Painting and statuary and architecture, coloring and illumination are to be combined into one beautiful whole. And through all, there runs the purposeful display of the development, the evolution, of the artistic organism.

"Period rooms" are used to provide the natural setting for portraits and landscapes. The style of the costume is to be harmonious with the architecture of the corresponding period,

and so growth from primitive state to sophistication will become readily evident.

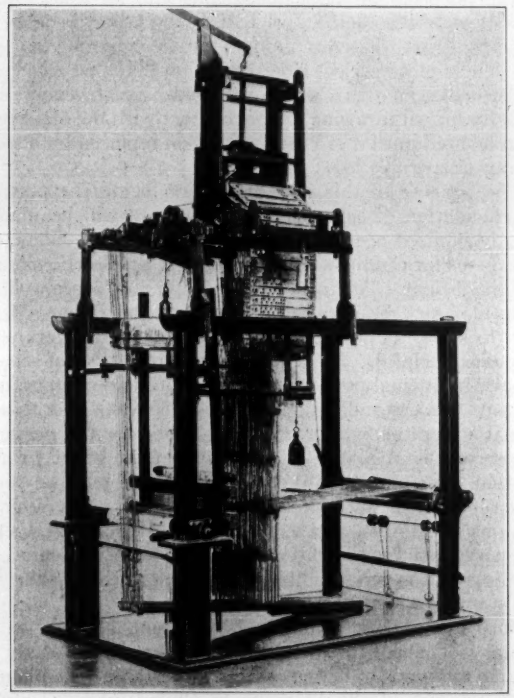
Exactly the same purpose underlies the establishment which we are planning. It shall be a place where the *principles* of science are emphasized, where the scientific fundamentals are displayed as they find application in industry, and where the growth of manufacturing and engineering processes are portrayed with the utmost possible clarity. The emphasis must always be upon the idea of development. The purpose shall be to show how the present, perhaps very complex, method has come about, what has been the scientific evolution which has taken place. In such an institution, the acquisition of detailed knowledge *and* the understanding of the whole process will of necessity go together.

There has come about another and vital change. In the old type of museum, the object most frequently seen was the "Please do not touch" sign. That sign in the modern science museums is almost as rare as some of the exhibits. The visitor is expected, even urged, to handle, to operate, the exhibits. When, in order to prevent injury to the uninitiated, a "Do not touch" sign has to be displayed, it is accompanied by another stating that the machine or device or process will be operated by the attendant, upon request. The visitor is at liberty to repeat his observations just as often as he finds it desirable to do so. And, just as far as it is possible to do so, every exhibit is to be made active, be made "to run." The "wheels go round" in the case of a machine, the chemical reactions of the manufacturing processes are carried out, the metals are deposited in any example of electrolysis, in every case there is a display of life and reality. The combination of these two abilities, the ability to touch, to handle, the exhibits, and the ability to "make them go," is the characteristic of the modern museum and is that feature which insures their greatest usefulness.

In the institutions of the older type, the aim was always to get originals. This fact was inherent in the very nature of the institution. Now it is true that the possession of at least a few pieces of apparatus with which some fundamental discoveries were made lends a tang, an atmosphere, which can be obtained in no other way. No electrical engineer, or

physicist, can fail to have a thrill when he stands in the Deutsches Museum in Munich, before the apparatus with which Heinrich Hertz laid the foundation for the development

FIG. 5.



Original Jacquard Loom.

of wireless communications. What must be the feeling of a textile man when he is in the presence of the original Jacquard loom in La Conservatoire des Arts et Metiers of Paris? And how must a member of The Franklin Institute thrill when he

can touch the original electrical machine of Franklin, or the coils with which Faraday made his immortal discovery?

The originals are like salt on food—they add a flavor and give distinction. But, as in the case of salt, a little goes a long way. A few great originals are enough. And, indeed, for the purposes of the modern museum, an exact copy is often of more use than an original. The latter, because it *is* the original, and therefore unique, must be guarded and often kept under glass or lock for protection. If one exact copy can be made, another can also be made—so that there is no necessity for withdrawing it from contact with the observers—it can be used until it is "used up," then replaced by a second without irreparable loss.

The purpose of this new institution being the portrayal and elucidation of scientific principles, use will be made of every recognized agency for successful teaching. Sometimes a chart—as for example, in a portrayal of an electric circuit—will be sufficient. At times a photograph may serve well, or a movie film may be required to show all the steps. Models made to scale, sectioned to show the internal structure, are enormously helpful. Models, on an enlarged scale of separate parts, or individual portions of the whole chain of steps, often facilitate understanding. Diagrams, copies, photographs, original apparatus, whatever is best suited for the particular purpose and is available, will be used in the effort to make scientific principles vividly clear. That this purpose can be carried out with success is shown in the great scientific museums of Europe, and especially of Munich and Vienna. The success attained in their purpose by these museums, and the enjoyment experienced by the visitors to them, show how greatly worth while such institutions can be.

During the past summer, I was sent abroad, as the Secretary of The Franklin Institute, in order to study the scientific museums of Europe before undertaking the planning of the museum of the Institute in Philadelphia. I visited museums in Paris, Munich, Vienna, Budapest, Jena, Cologne and London, in the expectation of obtaining information and ideas which would be of value in developing our own plans. This expectation was not disappointed. I have come back with reports, drawings, criticisms, suggestions concerning the

European institutions, and with an exalted conception of what such a museum should be, which will be of the greatest value in putting our plans into execution.

FIG. 6.

Front of Technische Museum.

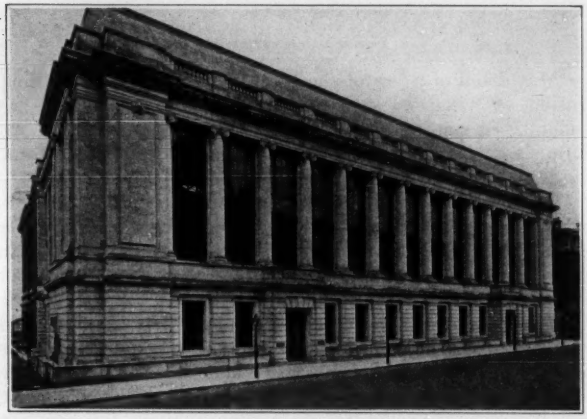
May I tell of a few of the things which I saw, as an illustration of what we desire to bring about? There is no difficulty in finding things to tell. The danger is that my enthusiasm will cause me to tell so much that I shall go beyond the limits of your endurance.

I recall my first visit to the Deutsches Museum in Munich. I had paid my respects to Dr. von Miller, the creator and life of that great institution. He had asked if he might give me a very cursory view of the collections before he turned me over to a young man. So we went first to the section on Physics. After going through the Court of Honor, where honor is paid to the immortals of German science, and through two rooms devoted to time keepers, clocks, watches, and sundials, we entered into Physics. Among the earliest things which we saw was a device to prove the relatively slight friction of a ball-bearing in comparison with a sliding bearing. That was easy. One twist of two wrists and the thing was done. But then the real question, *why is* rolling friction less than sliding friction? Can this be answered experimentally? I think it can be, and in an interesting manner.

Then there was a rotating table, on ball bearings, on which a man could stand within a rather closely fitting iron-pipe railing. Taking into his hands a special gyroscope set into brisk rotation, the man on the table underwent many twists and turnings when he tried to turn the gyroscope one way or another. He was led directly into some sort of an appreciation of the behavior of the gyroscopic compass and of the mono-rail car, and at the same time was immensely entertained!

We might well incorporate in the museum a section for the special benefit of college professors and ministers, on the subject of "perpetual motion." It would be a real contribution to human welfare to show the physical principles which demonstrate that perpetual motion is not a possibility—to attempt an experimental answer to the questions, "Why?" and "Why not?" I mention these two classes of good

FIG. 7.



Science Museum—London

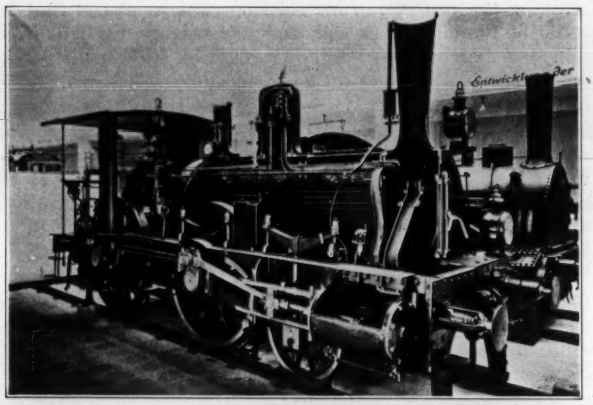
citizens because of the fact that every fake in physical science of the character of perpetual motion has victimized some of these distinguished persons.

We should want to be able to answer, or, much better, to enable a visitor to answer for himself, the question, "How can an aëroplane, which weighs tons, rise into the air in spite of the pull of gravity?" We can show this experimentally and strikingly in a very simple way, and we can show what are the things which determine whether or not an aëroplane will be able to leave the ground. All of this can be shown by simple experiments so that he who runs, or walks by, may understand.

We are all familiar with the steam locomotive but do we

really understand why it is able to pull a train of fifty loaded freight cars behind it? Is it enough to say that it is done by the expansive power of steam? We should propose to show by model engines cut away, so that all of the essential parts are visible, how the expansive power of a gas can possibly be made to do such a tremendous amount of work at such a great rate.

FIG. 8.



Sectioned Locomotive.

The radio telephone, marvelous as it is, has become one of the commonplaces of our lives. We take it as a matter of course. Veritable children can operate it, can repair it when it gets out of order, can talk of 'ticklers' and 'regeneration' and 'static,' quantities which ten years ago were hardly dreamed of. Yet, how much of *real* understanding is involved in such things? Very little, I fear. Would it not be an interesting and profitable thing to have shown by simple experiments the fundamentals underlying radio? I think it can be done and, also, that we can show, step by step, so that all normal men can understand, the development which has led from the crude apparatus of a few years ago to the exquisite scientific instrument which the radio is today. We

shall certainly make a valiant effort to make it all clear, and, in the process, to explain the working of that household marvel, the common telephone.

A question of domestic importance concerns our ability to match colors by artificial light. Can we do so successfully? Why, or, why not? I saw a beautiful attempt to make comprehensible the answers to these questions, at the Deutsches Museum. A pheasant, gorgeously feathered, rivalling the peacock in his coloring, was so placed that he could be illuminated at will, and successively, by light from different sources and of differing qualities. First, light from an ordinary carbon wick incandescent lamp was turned on the bird. He shone only fairly brightly; then light from a tungsten lamp was applied; the bird appeared brighter and more colored; then light from a so-called "day-light" lamp: the pheasant possessed all the beauty, apparently, which he showed in sunlight. Lastly, the light from a source of ultra-violet light was used—and the bird which had seemed so highly colored in reds and yellows, appeared as black as a black derby hat. The dependence of the apparent color upon the nature of the illuminant used, was clear beyond question.

What causes near-sightedness and what causes far-sightedness? How can these defects be remedied by glasses? How are such glasses ground? We shall try to show you.

The illustrations which I have taken have been from the realm of physics. Let us turn to Chemistry.

What is the difference between alchemy and chemistry? What is organic chemistry? And what is inorganic chemistry? How do they enter into our daily affairs?

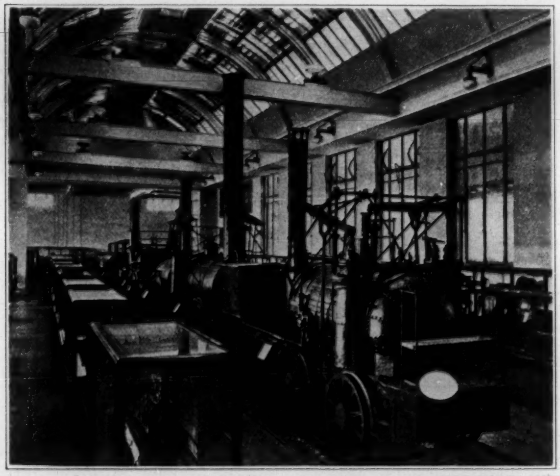
In one of the foreign museums there is the famous 'coal tar tree.' Starting with a lump of coal, the production of more than two thousand compounds is delineated, by a striking wall chart, in which is shown the exact 'descent' of each substance.

I think it would be an interesting thing to have a 'wood pulp tree.' Starting with the limb of a tree, such a "tree" would show the many things which are made from wood pulp —paper for our newspaper, cellulose, artificial silk for fabrication into silk stockings to be worn on limbs not at all wooden, and the many other materials derived directly from wood.

Take the glass industry. What is flint glass? Lead glass? Crown glass? How was glass originally made? How is it made today? What makes plate-glass? What is the U-viol glass?

We shall try to answer all of these, and other, questions by means of models of glass factories, by charts, by samples. We shall if possible, have a skilled glass-blower working at certain announced times, making apparatus which can later be used in

FIG. 9.



Original Locomotives.

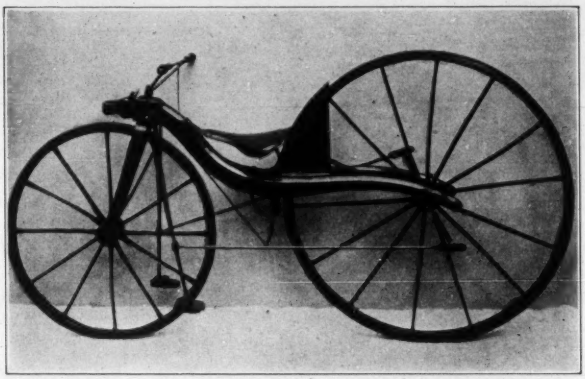
research. Few things prove more interesting to watch than the art of a skilled glass-blower. Perhaps we shall enable some young boys to find that they are meant by nature to be glass-blowers? Who can tell?

Philadelphia was the center of the chemical industries a century ago and has remained so to this day in certain lines of production. Models of factories or furnaces or plants, made to scale, will show how sulphuric acid or zinc oxide or lead storage batteries or any one of many other substances are

made commercially. And every effort and every suitable device will be used to make readily understandable all the scientific principles applied in these processes.

Consider engineering and industry. Pennsylvania and New Jersey are the birthplace of American railroads, and Philadelphia has been for decades the place of production of thousands of locomotives which have traversed all the "rails" of the world. This city has been the starting point for

FIG. 10.



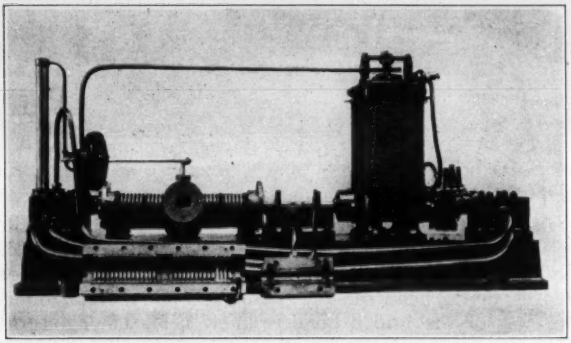
Bone-Racker Bicycle.

countless trolley cars which have extended urban and inter-urban transportation over the whole of this country. And hundreds of ships for commerce, for pleasure, for peace, for war, which have riven the waters of the "Seven Seas" and of all other seas, made their initial plunge into salt water from the banks of the Delaware.

These facts, coupled with the historical incident that one of the founders of The Franklin Institute was the first president of Pennsylvania Railroad, make it most appropriate that we should devote full attention to the history of transportation and to the portrayal of the expansions of science which have made modern transportation a possibility.

We shall portray the changing methods of travel from riding on the horse's back to the unforgettable voyage of the "Lone Eagle" in the *Spirit of St. Louis*, from the arduous journeys of the American Indian in his birch-bark or his "dug-out" to the luxurious and safe crossings of the *Leviathan*, from the miseries of the "bone-racker" bicycle to the comfort of the Lincoln car. And our constant purpose must be to show the logical evolution which has led from one vehicle to the next, from one method of transport to the next, and the

FIG. 11.



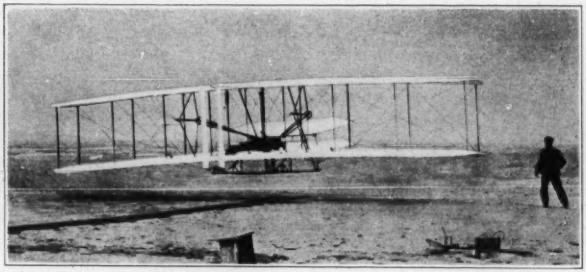
Early Steam Turbine.

fundamental discoveries which find their applications in the useful service of man. The exhibit devoted to transportation is one of the largest and most interesting in every museum because, probably, improved transportation has always been the goal which men constantly seek, and because of the fundamental importance of the subject.

So we shall try to make as plain as sunlight the action of steam engines, steam turbines, windmills, water-wheels, gas-engines, Diesel engines, electric motors, tidal motors and all other prime movers which do the work of man. We must show the development of the latest railroad flyer from the "*Rocket*" of Stephenson, the evolution of the *Aquitania* from

the "*Claremont*" of Fulton, the direct descent of Byrd's North Pole aëroplane from the Kitty Hawk machine of Wilbur and Orville Wright. In every step, the scientific "why" must be pointed out and made understandable.

FIG. 12.



Original Wright Aeroplane.

The growth of bridge-building must be pictured, from a single tree thrown down across a brook to the beautiful Delaware River bridge. The accessories which have made the latter bridge and its like possible must be shown: power dredges, diving bells, caissons, piling and pile drivers, and all the tools of the bridge builder. Few fields of engineering show so many inspiring examples of the conquest of nature by man's courage and intellect as the science of bridge-building. Every great new bridge has brought some new feature into the work, some improvement of former methods, some method of adopting ancient knowledge, or of applying modern information, to novel and trying problems.

Consider some of the problems which even the most ignorant of us must realize have to be solved when a tunnel is run under a great river, as the Pennsylvania Railroad tunnel under the Hudson River.

How is the hole through the earth and the rock and the mud made? How can men be enabled to work scores, and even hundreds, of feet below the surface of the water? What are the tools which make such things possible? How do such tools work? What are the advantages and the disadvantages

of electric tools in comparison with steam, or pneumatic, or mechanical tools? After the tunnel boring is made, how is the tunnel tube put into place? How is it fixed? How is it supported? What effect upon the railroad tunnel has the passage up the Hudson of a huge ocean liner? How many different ways might the tunnel work be done?

You can see readily enough what kind of problems might arise, what varied questions may demand answers. And I think you will realize what an interesting exhibit ought to be possible. Such an exhibit must give the answers required by means of physical experiments, if that be possible.

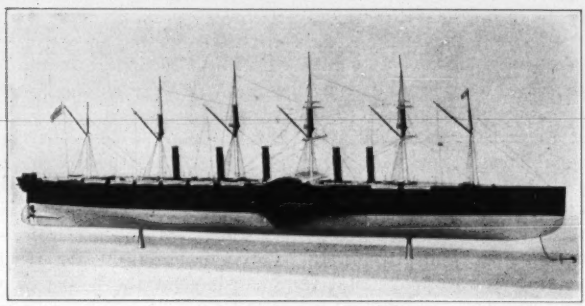
Of course one of the world's great engineering accomplishments is the Panama Canal. Problems which seemed insoluble were met and solved, new methods were planned, new tools were made and successfully used. Engineering feats on an unprecedented scale seem almost commonplaces in the Canal Zone! Locks large enough to pass a battleship, or an ocean liner, from one canal level to a different one, have been built and are in use, problems in drainage, in sanitation, in construction have been ingeniously solved. Can the solutions of these problems be portrayed experimentally? We shall certainly try to prove that they can be—for the instruction and training of all who are interested.

Probably no more generally attractive exhibit can be prepared than that which deals with the evolution of modern boats from the savage's dug-out, "ein-baum," as the Germans call it, through the craft driven by man-power or by winds and sails, down to the giant liners of today, or the Flettner motor ship. Some of the collections of ship models, especially that at Munich or in the Science Museum in London, are extremely interesting and attract great attention at all times. Such displays are especially impressive when, as in the Science Museum, models are constructed to the same scale and so show the growth and development from ship to ship. Four such models of Cunard ships, four boats which were the pride of the line when they were launched, show most strikingly the increases of size and of comfort of the ships of that great transportation company during the last thirty or forty years.

Such collections should not be merely attractive to the eye. They should always be regarded as teaching some application

of science to the uses of mankind. Such models can be used to illustrate the dependence of the sea-worthiness of a boat upon the shape of the hull, the distribution of the equipment, and the stowing of the cargo. Such models can be made to show what is meant by "Stream-line form" of the hull, and perhaps also, the dependence of the speed on such form, with unchanging power. One can readily demonstrate, experimentally, the behavior of the Flettner motor ship and can

FIG. 13.



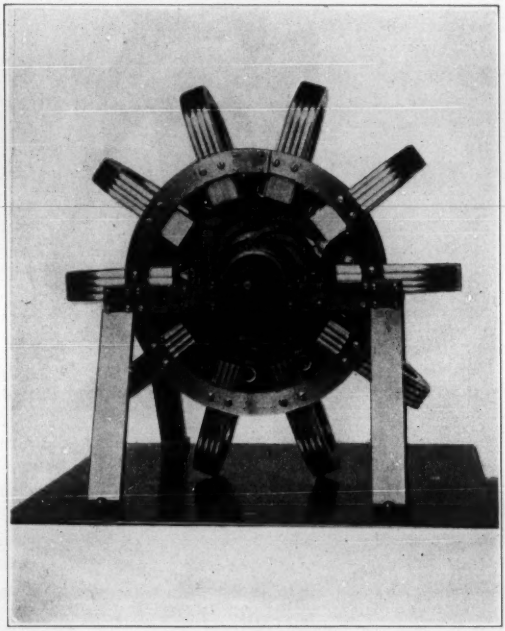
The Great Eastern.

"explain" its working. And one can show by very simple experimentation that the physical principle, or law, underlying the motion of the Flettner craft explains also various apparently unrelated actions, such as the curving of the pitched baseball, the production of the sensation of fullness of the ears when a rapidly running train goes through a closely fitting tunnel, or the behavior of the ball in "the ball and jet." Surely here is a chance to show the unification of science!

I recall a portion of the exhibit concerning boats of the Deutsches Museum of Munich in which the cabins, first or second or third class, and the corresponding dining saloons, are shown in their exact proportions. The engine rooms, erected to scale, with engines running, and the ships-bridge, displaying the signalling apparatus and the navigation instruments, are to be visited and inspected. Then, the onlooker is led to the promenade deck, where steamer-chair, steamer rugs

and the appliances for the comfort of the passengers are shown. There, beyond the rail, is shown a painted ocean! The illusion is so complete that the spectators receive a vivid impression of reality. The person who has never been near

FIG. 14.



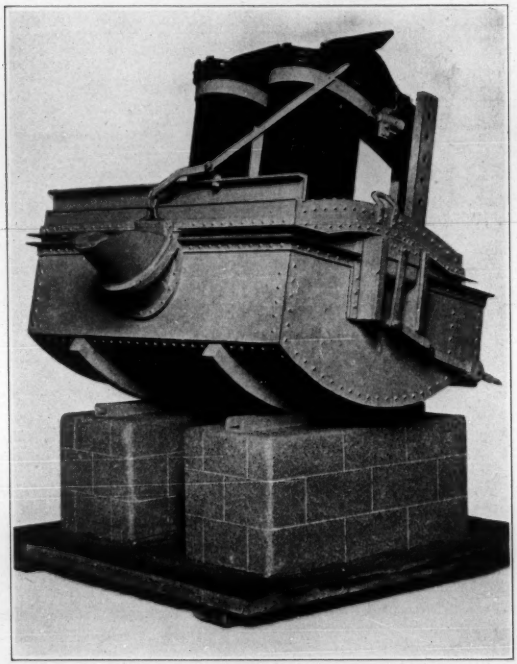
Early Dynamo.

the ocean may obtain a reasonable understanding of the atmosphere of a trans-oceanic steamer.

A necessary adjunct of ocean shipping, required that ships may be kept in good condition or repaired when damaged, is the dry dock, whether a fixed or floating dock. Working models of both types should be shown so that the veriest land-

lubber cannot fail to understand this great nautical tool and the ingenious applications of science which are made in the dry-dock structure and working.

FIG. 15.



Electric Arc Furnace.

In this era, when we talk, or think, of engineering and its practices, we come, sooner or later, to constructions and operations of electrical engineering. We are soon confronted by the marvels effected by the electrical men, hundreds of them, in lighting, in communication, in transmission of

power, in transportation, in construction of stupendous machines, in the erection of beautiful and powerful hydro-electric power-plants. In no field have more ingenuity and more exact knowledge been utilized than here. And in no community has greater progress been made, or more success been attained, in the application of electrical power to the home, to the factory, to daily life, than here in Philadelphia. The great power plants of the Philadelphia Electric Company and the magnificent Conowingo power plant on the Susquehanna River show the highest efficiencies yet attained by man in the generation of electric currents by either steam or water power. They are, as yet, the last word in electrical planning and construction. They are due in large part to the engineering knowledge, the administrative ability and the indomitable will of the late honored president of The Franklin Institute, Dr. W. C. L. Eglin, Chief Engineer of the Philadelphia Electric Company. We should be remiss if we did not show, as a special feature of our electrical exhibit, working models of some of these great engineering structures which have given to Philadelphia a position of fine leadership. We shall strive earnestly not to be remiss in this respect.

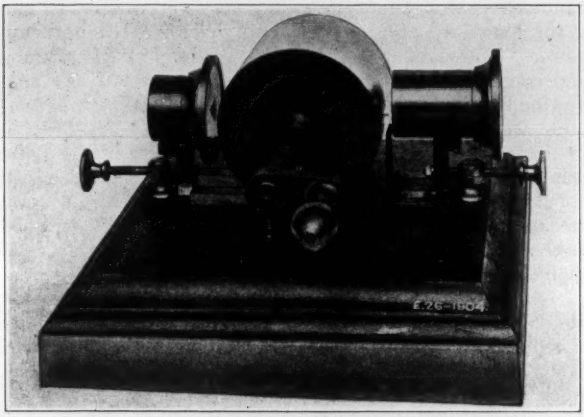
A portion of our agreement with the Benjamin Franklin Memorial, Inc., calls for the establishment and maintenance of an exhibit of the graphic arts as they were at the time of Franklin's activity as a printer. We should expect to display much more, for we should want to show many things which Franklin had not even dreamed of. We shall want to show printing as it was done in Franklin's shop and as it is done today in great modern plants. We shall portray the processes of engraving as practiced then, and as they are utilized today, and also how they are facilitated by the application of electrolysis and photography. We shall demonstrate the making of paper, whether rag or wood-pulp, and book-binding, the development of printing and typesetting machines and the several auxiliaries of the present printer's art.

One of our ambitions is to show photography in such a way that a "tyro" can have some informed appreciation of it, as well as learn the actual manipulations involved. It will perhaps be possible to set forth the growth of modern photographing from the labors of Daguerre to those of Eastman, on

through the moving picture, through color photography to the color-movie. The preparation of such an exhibit offers an intriguing problem.

The analysis, recording and reproduction of speech offer another enticing region for experimental demonstration. It should, I think, be readily possible to start with the manometric flame, show the varying quality of the sounds produced

FIG. 16.



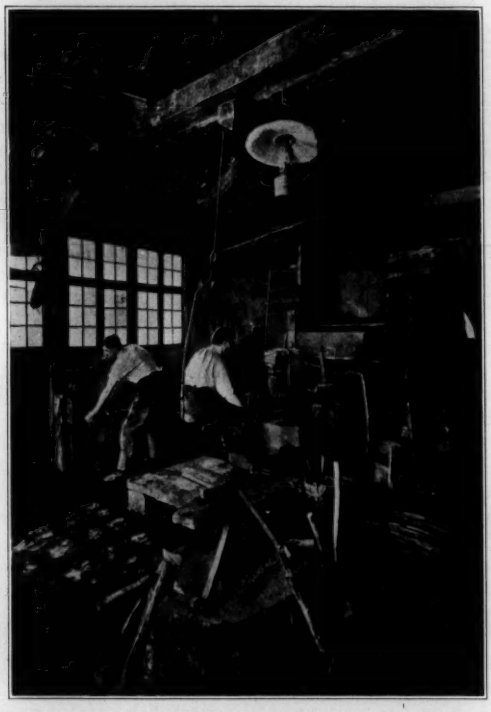
Original Edison Phonograph.

with changes of shape of the sound waves; then, to show the recording of such waves by the crude original apparatus of Edison and by the methods of Berliner and others, as well as to make clear the ways which have been, or are now, practiced in reproducing such sounds. It should not then be over difficult to demonstrate the production of synchronism between light and sound, say by the method of Bristol, and thus to make clear the evolution of the successful talking motion picture.

In an effort to make wholly clear to you what are to be the purpose and nature of the much discussed museum, many illustrations have been taken from various fields of physical

science. Even though a considerable number have been described, they represent only "samples" of the almost countless examples of the applications of science to man's use

FIG. 17.



Iron Workers Shop.

and welfare which might have been chosen and which will be found displayed in the completed museum. We might have chosen many more illustrations, from engineering, from mining, from geology, from manufacturing, from domestic

affairs, from city life, from the farm, from our work, from our play. Perhaps what have been chosen will suffice.

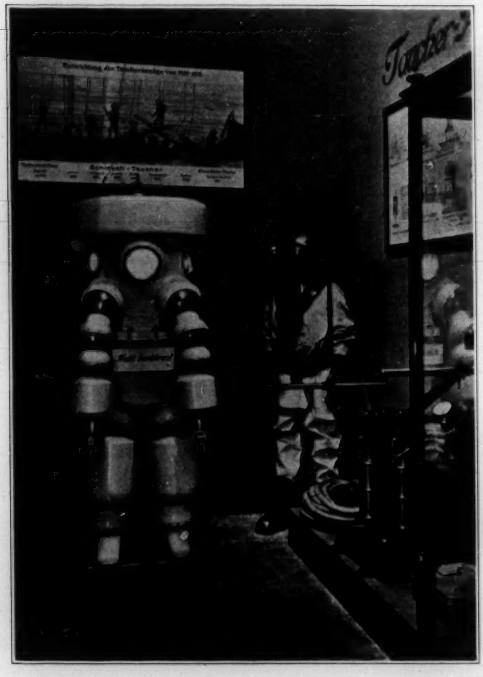
We hope earnestly that the examples cited will show two things: how excitingly interesting such a museum as has been planned can be, and that it should be a place where many a young person may be aided, through increased knowledge, to learn of his own abilities and tastes and, therefore, to make a wiser choice of his life's work. That the first of these results may be confidently hoped for is indicated by the effects of the great European scientific museums upon the visitors to them. It is the common thing to hear of the traveler who goes to Munich to see all the beauties of that city and goes first to the Deutsches Museum—"to get through with that"—and who then goes again and again and again, to the complete neglect of all other museums and collections. One of the three or four leading physicists of the United States said, when asked if he had gone to the Deutsches Museum and if he had enjoyed it: "I spent three full days there, and wish that I might have had three full weeks." One of the great industrialists of this country volunteered the statement, "I never go to London without making at least one visit to the Science Museum in South Kensington." We mean to give to Philadelphia an equivalent institution.

If the museum performs the second service which is expected of it and aids young people to make wise choices of vocation, then it will indeed be a worthy and living memorial to Benjamin Franklin. You will recall Franklin's expression of approval of his father's action in taking him to visit various industrial plants in the hope that he would be thereby aided in choosing his line of future activity. No one could value more highly than Franklin would have done an institution which would have as an important by-product of its activities, helpfulness to young people in the choice of their occupations for life.

One thing the museum will accomplish, whatever else it may, or may not, bring about. It will give to the young people of school age a realization of the vitality and importance of scientific knowledge. It will show convincingly how valuably science may be applied for man's advantage. It cannot fail to inculcate, by analogy, a belief in the value of

all knowledge. The museum will be a vital adjunct to the educational facilities of the city.

FIG. 18.



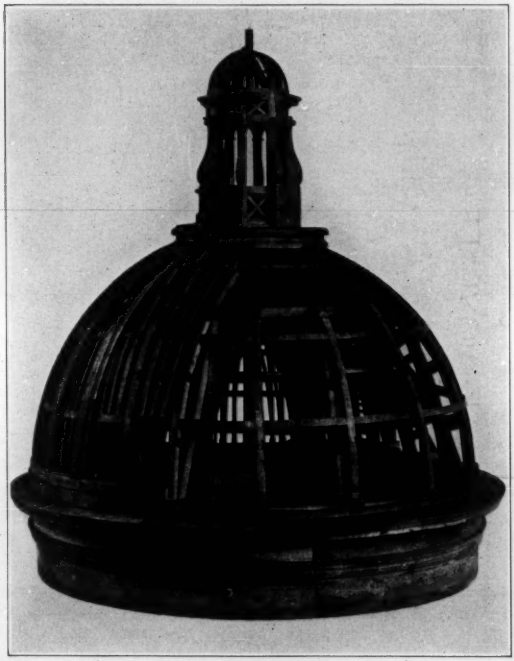
Deep Sea Diver.

I have refrained deliberately from mentioning, up to this time, one field of scientific thought in which this new institution can contribute in a striking way to the enjoyment and enlightenment of the people—the science of astronomy.

Our earliest progenitors lived under the stars, and could not avoid thought, even wonderment, about them and their

mystery. The literature of the ancients of every nation abounds in reference to the heavenly bodies. The very names of the constellations show the imagination which was applied in their thoughts about the stars. Under modern

FIG. 19.



Framing of Cathedral Dome.

conditions of living, especially in the great centers of population like Philadelphia, a knowledge of the stars—often even a view of them—is obtained only with difficulty. So it is but natural that the old intimate acquaintance with the stars should have become very rare. We doubtless know tre-

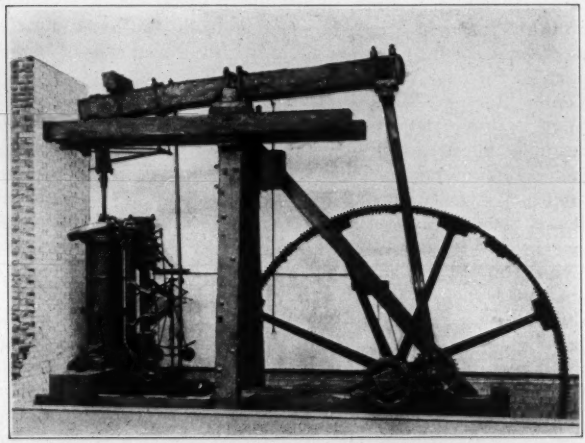
mendously more of the science of the stars. I doubt if we know them so well as one of the wonders of the universe as our fathers did.

We wish greatly to be able to show in the museum a great planetarium which portrays the heavens so beautifully and in such glory that one gets a splendid conception of them. This great scientific instrument projects upon the inner surface of a hemispherical dome thousands of lights which represent accurately and in approximate magnitude the fixed stars as we behold them on a clear night. Other, and special, lights portray the Sun and its planets, the Earth and its satellite, Venus, Mercury, Mars, Jupiter and its moons, Saturn with its rings, in proper relative magnitude and position and, by their motions, the motions of these planets in their proper periods and orbits. The motions of a year can be shown in four minutes or sixty seconds or seven seconds. One can see clearly the elliptical form of the orbits, without waiting years, or centuries, to do so. One readily realizes the effect of the inclination of the plane of the ecliptic in producing the earth's seasons. One sees why the present 'pole-star' has not always been our 'pole star' and one can see what star will be our 'pole-star' thousands of years hence. By easy and suitable regulation, the audience can be shown the heavens as they appear to an Eskimo, or as they might have appeared to Captain Scott at the South Pole, or as they will appear to Commander Byrd when he reaches that remote axis, assuming that he will have clear nights. By other adjustments, the sky can be depicted as it appeared to Abraham thousands of years ago, "as he tended his flocks by night," or as it will appear to the "Last American" thousands of years hence. The great beauties of the skies are brought out with such force and effectiveness that the onlooker exclaims with the Psalmist, "The heavens declare the glory of God and the firmament showeth His handiwork." At least, that was the effect upon the writer when he saw this great product of man's intellect during this past summer.

In addition to the planetarium, we shall have telescopes, both reflecting and refracting, for direct visual observations of the heavens, and enough of other types of apparatus to give some insight into the wonders and the successes of modern

astronomy. We are promised copies of the finest photographs ever taken of many spiral nebulæ, eclipses, comets and other astronomical objects and phenomena. We shall surely have an astronomical exhibit which will be worthy of this home of Rittenhouse, if we have a museum at all!

FIG. 20.



Ancient Steam Engine.

I have tried to give you some insight into the vision we have had of a great new home of science and scientific wonders, built and maintained for the benefit and enjoyment of Philadelphia and its visitors. We hope it will gain your approval and support. We shall earnestly strive to make it a place of profit and pleasure for you and your children and your children's children for uncounted generations.

THE POSSIBILITY OF DETECTING INDIVIDUAL COSMIC RAYS.

BY

W. F. G. SWANN, D.Sc.

Director, Bartol Research Foundation of The Franklin Institute.

THE purpose of the present paper is to show that, in view of the enormous energy available for ionization in a single cosmic ray, and of the relatively small number of ions produced per second by the rays in a vessel of moderate size, the ionization produced should occur in spurts which may be observable under suitable conditions.

According to Millikan and Cameron, the rays observed near the earth's surface have an absorption coefficient of about 0.1 per meter of water, and produce about 1.4 ions per c.c. per second in air at atmospheric pressure.[1]

Using Dirac's formula,[2] the value of $h\nu$, the cosmic ray energy, corresponding to $\mu = 0.1$ per meter of water is

[1] In Millikan's and Cameron's paper, *Nature*, Supplement, Jan. 27, 1928, the authors quote the present writer as having obtained the value 0.75 ions per c.c. at the summit of Pike's Peak. It must be remarked that the latter quantity is the increase per atmosphere in the ionization per c.c. at the part of the ionization-pressure curve where the slope is least. This quantity has no very simple relation to the ionization per c.c. at atmospheric pressure. It should be less than the latter quantity. In discussing the relation between pressure and ionization, the writer demonstrated the following theorem in the Bulletin of the National Research Council, No. 17, pp. 54–77, 1922. The increase in ionization per atmosphere increase in pressure in a vessel is greater than the portion of the ionization due to primary and secondary action arising *in the gas within the vessel* at one atmosphere. (Footnote to above: It would not be quite safe to extend this argument to imply that the ionization here referred to was necessarily greater than the true natural ionization in the open air, since a portion of the ionization in a volume of the external air occupying the space of the vessel would result from secondary radiations originating outside of that volume.)

The words italicized in the above, and the footnote are very important since, in the case of long range secondary radiation, a considerable portion, and probably the main portion of the ionization comes from secondary radiation originating outside the vessel, or in the walls of the vessel.

[2] Dirac, *Proc. Roy. Soc.*, A 111, 423, 1926.

(Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.)

13×10^{-5} ergs per cosmic ray. If all of this energy is available for ionization, the number of ions producible by a cosmic ray by direct and secondary actions should be $h\nu/Ue$, where U is the ionization potential. Taking U as corresponding to 15 volts for nitrogen, we find

$$\text{Number of ions per cosmic ray} = \frac{h\nu}{Ue} = 0.54 \times 10^{7}.$$

If the average rate of production of ions by cosmic rays is N ions per c.c. per second at atmospheric pressure, the average number of primary cosmic rays absorbed per second in a volume W is n, where

$$n = \frac{NUeW}{h\nu} \qquad (1)$$

Of course, all of the ions resulting from the absorption of a primary quantum in a volume W do not make their appearance in that volume. Many of them are produced by secondary radiations which go outside of the volume. Again, secondary radiation originating from the absorption of quanta outside of the volume enter it and produce ions there. The rate of production of ions in a volume is, however, equal in air to $h\nu/Ue$ times the average number of primary quanta absorbed in the volume per second.

If the ions produced by the direct and indirect results of the absorption of a primary quantum were all produced in the immediate vicinity of the point of absorption of the quantum, we should obtain in our volume W, n spurts of ions per second. As a matter of fact, we should under these conditions obtain 0.54×10^{7} ions at each spurt; and, as may be seen by inserting $N = 1.4$ in (1) we should obtain only $1.4\ W/0.54 \times 10^{-7} = 2.6 \times 10^{-7}\ W$ spurts per second.[3] In other words, in a volume of 1 liter, there would be an interval of 4,000 seconds

[3] Incidentally, this conclusion has an interesting bearing upon experiments designed to test whether radioactivity may be caused by disintegration of the radioactive atoms by cosmic rays. Thus, in a test made with, let us say, 10^{-11} grams of polonium, which would give a saturation of about 0.3 e.s.u., we should have to wait about 10^{16} seconds, or about twenty million years between two successive occasions on which a cosmic ray became absorbed in our radioactive specimen.

between each spurt. In practise, the conditions are otherwise. The ions are produced for the most part by secondary radiation which operate far from the place of absorption of the original quantum.

We shall first consider an ideal problem which probably does not represent the facts in their details, but which will nevertheless illustrate the general principles which enter into a consideration of the problem. We shall suppose that the secondary radiation resulting from the absorption of a primary quantum may be regarded as producing ionization (in ions per c.c.) which falls off according to the symmetrical exponential law,

$$I = \frac{I_0 e^{-ar}}{4\pi r^2},$$

where r is the distance from the point of absorption of the original quantum. I_0 is determined by the condition

$$\frac{h\nu}{Ue} = I_0 \int_0^\infty \frac{4\pi r^2 e^{-ar}}{4\pi r^2} dr = \frac{I_0}{\alpha}.$$

Hence

$$I = \frac{h\nu\alpha}{Ue} \frac{e^{-ar}}{4\pi r^2}.$$

Let us now consider the ionization produced in a spherical vessel of radius a, Fig. 1, as a result of the secondary radiations originating from the absorption of a primary cosmic ray at a point P at a distance b from the center of the sphere. The part of this ionization per c.c. at the piont A is

$$\frac{h\nu\alpha}{4\pi Ue} \frac{1}{k^2 + b^2 - 2bk\cos\theta} e^{-al}, \tag{2}$$

where $AO = k$, and $AP = \sqrt{k^2 + b^2 - 2bk\cos\theta} = l$.

The number of ions produced in the element of volume $k^2 \sin\theta\, dk d\theta d\varphi$ is

$$\frac{h\nu\alpha}{4\pi Ue} \frac{k^2 \sin\theta dk d\theta d\varphi}{k^2 + b^2 - 2bk\cos\theta} e^{-al}. \tag{3}$$

Hence, since the exponential factor is less than unity, we have for the total ionization ΔN within the vessel

$$\Delta N < \frac{h\nu\alpha}{4\pi Ue}\int_0^a k^2 dk \int_0^\pi \frac{\sin\theta d\theta}{k^2 + b^2 - 2bk\cos\theta}\int_0^{2\pi} d\varphi, \quad (4)$$

$$\Delta N < \frac{h\nu\alpha}{2Ueb}\int_0^a k \log\frac{b+k}{b-k}dk,$$

$$\Delta N < \frac{h\nu\alpha}{2Ueb}\left[ba - \frac{b^2 - a^2}{2}\log\frac{b+a}{b-a}\right].$$

$$\Delta N < \frac{h\nu\alpha a}{2Ue}\left[1 - \frac{(b-a)(b+a)}{2ba}\log\frac{b+a}{b-a}\right]. \quad (5)$$

For the case where P lies outside, or at any rate, not inside, the vessel ΔN has its largest value for $b - a = 0$, and for this case

$$\Delta N < \frac{h\nu\alpha a}{2Ue}.$$

If we should fill the vessel to p atmospheres pressure, and if we should assume the ionization proportional to the pressure, we should have [4]

$$\Delta N < \frac{h\nu\alpha pa}{2Ue}.$$

Cosmic rays absorbed at points P within the radius a, give, in the whole volume, an ionization greater than that resulting from those absorbed on the boundary of the volume, as may be seen from (5). It must be admitted, however, that this conclusion would be modified in practice by the fact that the secondary ionization would not spread out uniformly in all directions.

Let us suppose that 10^5 ions is the least number which can be detected, since the collection of this number would result in a deflection of 2.5 mm. in an electrometer sensitive to 3,000 divisions per volt, with a capacity equal to 20. Then for *every* cosmic ray absorbed within the vessel to give rise to a measurable effect we must have

$$a > \frac{10^5 \times 2Ue}{\alpha ph\nu}.$$

[4] There is some doubt as to whether ΔN would be proportional to the pressure up to 100 atmospheres, and if it varied less than according to the law of proportionality, n would be reduced on this account also.

Putting $h\nu/Ue = 0.54 \times 10^7$ as already found, putting $\alpha = 4 \times 10^{-5}$ which is about the same as the absorption coefficient of the γ rays from radium C, and putting $p = 100$ atmospheres, we find

$$a > 10 \text{ cms.}$$

With any such radius as this, the exponential factor $e^{-\alpha l}$ in (2) is quite negligible. For, with the above value of α multiplied by 100 to take account of the pressure, αl would only amount to 4×10^{-2}. Thus, in view of this circumstance, our signs $<$ and $>$ might have been written $\leq$ and $\geq$ respectively, all the way through, and our final conclusion is that to obtain a spurt of 10^5 ions as the ultimate result of the absorption of a primary quantum at the surface of the sphere, we must have

$$a \geq 10 \text{ cms.}$$

The number of primary cosmic rays effective per second in giving measurable spurts of ions are consequently those absorbed per second within the volume $\frac{4}{3}\pi a^3$. From (1), this number is $\frac{4}{3}\pi a^3 (NUe/h\nu)p$, where the factor p has been introduced to account for the enhanced absorption of cosmic rays as a result of the pressure. To obtain 10 spurts per second, we must have $a = 45$, which would be impracticable at 100 atmospheres. To obtain 1 spurt per second from cosmic rays absorbed within the vessel we must have a about 21 cms., and to obtain 1 spurt in 10 seconds, we must have a about 9.7 cms., which is within the range of practicability.

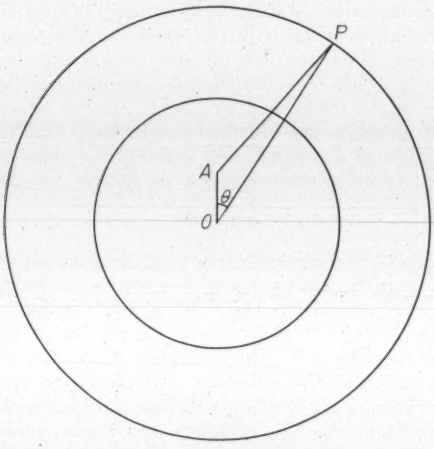
A METHOD OF INCREASING THE POTENTIALITIES OF THE EXPERIMENT.

The element which acts unfavorably to the purpose of the experiment is that concerned with the fact that the number of primary cosmic rays absorbed per unit of volume is so small that it is very rarely that a cosmic ray is absorbed so near to the vessel as to cause by its secondary radiations a large ionization therein. We may improve matters in this respect by surrounding the vessel with a highly absorbing material such as lead.

Thus, using Fig. 1 in an altered sense, and with the ionization chamber surrounded by lead, suppose we consider a

sphere of radius a surrounded by a lead shell whose outer radius is R. We shall neglect the variation of the intensity of the primary cosmic rays throughout the region of this shell. Of the cosmic rays generated in the shell, those produced on its

FIG. 1.



exterior will be the least efficient in giving rise by secondary radiations to ionization in the ionization chamber. According to (2) modified to fit the present case, the ionization per c.c. at a point A in the vessel resulting from a primary cosmic ray absorbed at a point P is

$$\frac{h\nu\alpha}{4\pi Ue}\frac{e^{(-\alpha r_1+\alpha r_2)}}{R^2+k^2-2Rk\cos\theta}$$

where r_1 refers to the part of AP which is in the air and α_2 and r_2 to the part in the lead. If then, the exponential were negligible, we should have for the above

$$\frac{h\nu\alpha}{4\pi Ue(R^2+k^2-2Rk\cos\theta}.$$

Again, proceeding as before, we find for the total number of ions produced in the vessel as a result of the absorption of the primary quantum at P,

$$\Delta N = \frac{h\nu\alpha a}{2Ue}\left[1 - \frac{(R-a)(R+a)}{2aR}\log\frac{R+a}{R-a}\right].$$

For a given value of a this, of course, has its greatest value when $R = a$. For this case, however, the number of cosmic rays caught by the shell would be just equal to that already calculated for this case. If we make $R - a = 2$ cms., and $a = 15$ cms., the corresponding value of ΔN is $2.7 \times 10^7\alpha$. If we should raise the pressure in the vessel to 100 atmospheres and assume proportionality, the corresponding value of ΔN would be $2.7 \times 10^9\alpha$ and if $\alpha = 4 \times 10^{-5}$, the corresponding value of ΔN would be 1.0×10^5 and would be measurable. Moreover, the neglect of the exponential is roughly justified for the above conditions, as may readily be verified.

Now, however, we secure from the lead, an advantage in respect to the number n of cosmic rays which contribute per second measurable amounts of ionization ΔN corresponding to the above calculation. For the number we have, from (1), after taking account in addition to the cosmic rays caught in the ionization chamber,

$$n = \frac{4}{3}\pi(R^3 - a^3)\frac{NU_e}{h\nu}\frac{D_l}{D_a} + \frac{4}{3}\pi a^3\frac{NU_e}{h\nu}p,$$

when D_l/D_a is the ratio of the density of lead to that of air at atmospheric pressure, i.e., 0.9×10^4. Inserting $N = 1.4$, $h\nu/Ue = 0.54 \times 10^7$ as already used, and the above values of R and a, we obtain $n = 13$. Thus, with the above apparatus we should, on the basis of the above assumptions have obtained 13 spurts of ions per second, of amount greater than 10^5 ions. By choosing the volume of the lead one-tenth of the above, n would be reduced to 1.3 per second.

Of course, the assumption we have made cannot be expected to be correct in detail. In particular, the assumption of a symmetrically distributed secondary radiation dying off exponentially must be incorrect. Nevertheless, the foregoing calculations are sufficient to show the practicability of at-

tempting to detect effects due to the absorption of individual cosmic rays.

An experimental difficulty presents itself in respect to the time taken to clear out the ions in the case of a high pressure in the ionization chamber, for, in view of the relatively small mobility of the ions, a large electric field would be necessary to clear them out in such a time as to produce the phenomenon of a recognizable spurt.

Another type of assumption which probably departs from the facts in the opposite extreme to that already made, is to the effect that the secondary radiation may be considered as originating from the point of absorption of the primary ray, and then passing through space with little ionization except for a certain distance e_a (measured in air at atmosphere pressure) at the end of its path. Let us now suppose our ionization chamber of radius a surrounded by a shell of lead, as before. On working out the number of cosmic rays effective in producing spurts of ions, we obtain an expression of the same order of magnitude as in the last problem considered, except that a^3 is replaced by $a^2e_lD_l/D_a$, i.e., by a^2e_a where e_l is the range of the active part of the secondary ionization ray as measured in lead, If e_a is comparable with a, the value of n deduced is comparable with that already found.

It would, of course, be possible to develop the detailed story of the ionization of the secondary radiation by considering the successive transformations due to the Compton effect, but it seems hardly necessary to do this in order to illustrate the possibilities inherent in an experiment of the above kind.

THE TRANSMISSION OF SOUND THROUGH SEA WATER.

BY

LIEUTENANT (J.G.) JERRY H. SERVICE, E.E., Ph.D.

U. S. Coast and Geodetic Survey.

INTRODUCTION. WORK OF HECK AND SERVICE ON SPEED OF SOUND IN SEA WATER.

In 1924 Heck and Service published tables [1] giving the speed of sound in sea water at all depths, temperatures and salinities likely to be encountered in ocean waters. These tables were based upon the independent suggestion of Service in the fall of 1923 that if adequate elasticity and density data were available for sea water the speeds could best be obtained by computation by Newton's equation. Fortunately adequate elasticity data had been made available by the labors of V. W. Ekman [2] and excellent density data had been obtained by Martin Knudsen, Carl Forch, S. P. L. Sörensen and J. P. Jacobsen and published with due acknowledgements by Knudsen in several publications. V. Bjerknes and J. W. Sandström had published [3] tables, based upon the work of Ekman and of Knudsen and his collaboraters, giving the densities and specific volumes of sea water throughout the whole range of physical conditions, and with such small pressure intervals that the elasticities could be obtained by tabular differences. References to Knudsen's publications can be found in that of Bjerknes and Sandström.

At first sight it would seem to be much better to use Ekman's elasticity results directly, together with the density data published by Bjerknes and Sandström, in computing the speeds of sound. But Ekman stated that his elasticity data might be in error by as much as one per cent., which would mean that the speeds of sound computed by this much more laborious, although apparently more accurate, method might be in error by as much as 0.5 of one per cent. It was estimated that in speeds computed by the less laborious method of tabular differences from Bjerknes and Sandström's Tables, errors due to the method of computation would never exceed 0.5 of one per cent., and hence that speeds thus computed

would be of the same order of accuracy as if computed by the apparently more precise method.

Heck and Service used the isothermal elasticities of the water in computing their tables of speed, and included in a separate table corrections to these speeds to take care of the adiabatic conditions that might obtain during transmission; they expressed doubt at the time of publication (1924) as to whether these adiabatic corrections ought to be applied. The writer's experience with echo sounding and radio-acoustic position finding and his consideration of the matter since 1924 have convinced him fully that transmission takes place under adiabatic conditions.

The accuracy of the tables of Heck and Service, when the adiabatic corrections are applied, has been rather well confirmed by experiment and it is considered worth while to reproduce those tables in condensed, skeleton form in this publication. This has been done in Tables 1, 2 and 3, which indicate the manner of variation of the speed of sound in sea water with depth, temperature and salinity, respectively. The solid curves in Fig. 1 are plotted from the values of Heck and Service in Tables 1, 2 and 3. Attention is called to the following facts that are brought out by these tables and curves.

1. Speed increases with temperature approximately 0.2 of one per cent. per degree Centigrade.

2. Speed (at the given depth) increases quite regularly with depth, about 0.2 of one per cent. per 100 fathoms.

TABLE 1.

Variation of Speed of Sound in Sea Water with Depth.

Temperature, 0° C. Salinity, 35 parts per 1000. Depths are in fathoms; speeds, in meters per second.

Depth.	Speed Heck and Service.	Speed British Admiralty.
0	1450	1445
500	1464	1462
1100	1482	1482
1700	1504	1502
2100	1516	1515
2700	1537	1534
3300	1561	1554
3700	1575	1567
4300	1592	1586
4700	1606	1598

TABLE 2.

Variation of Speed of Sound in Sea Water with Temperature.

At the Surface. Salinity, 35 parts per 1000. Temperatures are in degrees Centigrade; speeds, in meters per second.

Temperature	Speed Heck and Service.	Speed British Admiralty.
0	1450	1445
5	1470	1467
10	1490	1487
15	1507	1504
20	1522	1519
22	1529	1524
24	1535	1529
26	1539	1534
28	1542	1539
30	1547	1543

TABLE 3.

Variation of Speed of Sound in Sea Water with Salinity.

At the surface. Temperature, 0° C. Salinities are in parts per 1000; speeds, in meters per second.

Salinity.	Speed Heck and Service.	Speed British Admiralty.
31	1445	1440
32	1446	1442
33	1448	1443
34	1449	1444
35	1450	1445
36	1451	1447
37	1452	1448

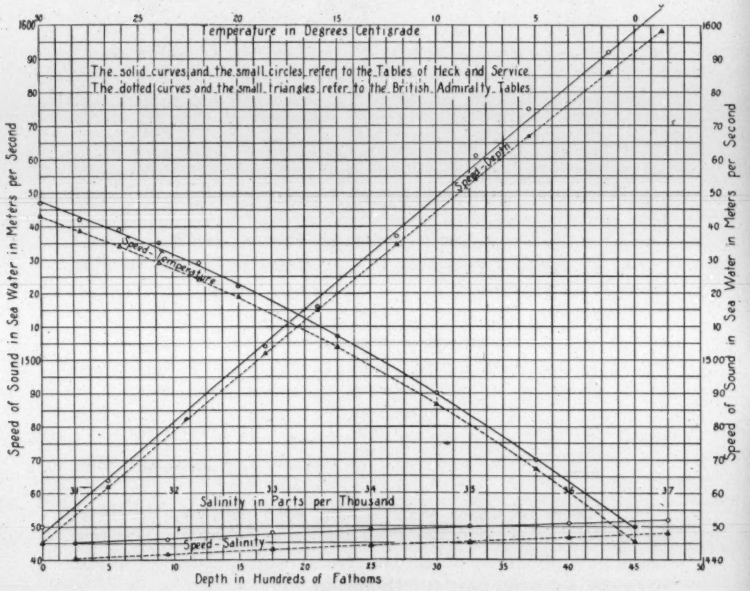
3. Speed increases very slowly with salinity, the total increase from 31 parts per thousand to 37 parts per thousand being only about 0.7 of one per cent., roughly about 0.1 of one per cent. for each part per thousand.

BRITISH ADMIRALTY TABLES OF THE SPEED OF SOUND IN SEA WATER COMPARISON WITH THE TABLES OF HECK AND SERVICE.

In 1927 the British Admiralty [4] published an excellent and very complete set of tables of the speed of sound in water, which were computed and prepared by Mr. D. J. Mathews on the basis of Newton's equation from the same elasticity and density data as were used by Heck and Service. Mr. Mathews, however, used Ekman's elasticity data directly,

thus avoiding small errors due to the method of computation to which the tables of Heck and Service are liable. Tables 1, 2 and 3 and Fig. 1, which show a fair selection of corresponding values of Heck and Service and of the British Admiralty, indicate the order of magnitude of those small errors. The

FIG. 1.


Temperature in Degrees Centigrade
The solid curves and the small circles refer to the Tables of Heck and Service.
The dotted curves and the small triangles refer to the British Admiralty Tables.
Speed-Depth
Speed-Temperature
Speed-Salinity
Salinity in Parts per Thousand
Depth in Hundreds of Fathoms
Speed of Sound in Sea Water in Meters per Second

British Admiralty tables are free from tabular irregularities, as shown by the dotted curves of Fig. 1, and as might be expected. The maximum discrepancy between the two sets of tables is about 8 meters per second, or about 0.5 of one per cent. The British Admiralty speeds are systematically lower than those of Heck and Service by about 4 meters, or about one-fourth of one per cent. due simply to the difference in the methods of computation. It must be remembered that these

differences are of the same order as the probable errors in the speeds due to the probable errors of the very excellent experimental data of Ekman.

From the standpoint of convenience for echo sounding work, where the soundings are taken in fathoms the tables of Heck and Service including the application of the adiabatic correction involve less computation in their use than do those of the British Admiralty. For echo sounding work where the soundings are taken in meters and for radio-acoustic ranging where distances are required in meters, the British Admiralty tables involve very little, if any, more computation than do the tables of Heck and Service.

TABLE 4.

Comparison of the Results of Precise Measurements of the Speed of Sound in Sea Water with the Corresponding Values in the Tables of Heck and Service and of the British Admiralty, Respectively.

All measurements were made in comparatively shallow water.

Experimenter.	Temperature deg. Cent.	Salinity parts per 1000.	Measured Speed m/sec.	Speed Heck and Service m/sec.	Speed British Admiralty m/sec.
Stephenson [6]	−0.3	33.5	1,453	1,449	1,442.2
Marti [7]	15	32.3	1,504.15	1,503	1,500.9
Wood, Browne, Cochrane[8]	6	35	1,474.0	1,474	1,472.0
Wood, Browne, Cochrane[8]	7	35	1,477.3	1,478	1,476.1
Wood, Browne, Cochrane[8]	16.95	35	1,510.4	1,514	1,510.4
Eckhardt [13] See Note	13	33.5	1,492.3	1,498	1,495.5

Note.—The author took part in Eckhardt's measurements of speed and knows his measurements to have been of very great precision indeed. The distance was about 100,000 meters. Unfortunately, however, inadequate temperature observations were made over the range between bombs and hydrophones, so that his temperature as given above is perhaps a little higher than the true mean value between surface and bottom over the whole range.

The British Admiralty has rendered a great service to navigators by its Table 1 in which are given sound speeds to be used in echo soundings in various ocean areas. The navigator is not in a position either to measure or to search out in the literature the temperature and salinity conditions obtaining at various depths in the regions where he may wish to take echo soundings. Tables should be prepared for his

use giving him the correct speed of sound to use for a sounding of approximately a given depth in a given ocean area. This the British Admiralty has done in its Table 1. Heck and Service have published [5] convenient data of this kind for the whole Pacific Ocean.

A further comparative test of the tables of Heck and Service with those of the British Admiralty can be made by checking both against the results of precise measurements of the speed of sound in sea water under known conditions of temperature and salinity. Such a test is applied in Table 4.

MEASUREMENTS OF THE SPEED OF SOUND IN SEA WATER BY THE GERMAN SURVEY AND RESEARCH SHIP METEOR.

The German Atlantic Expedition has, upon some 250 stations occupied by the Survey and Research Ship *Meteor*, obtained simultaneous pressure soundings, echo soundings and serial temperature and salinity measurements. These 250 stations are distributed from the Antarctic Ocean through the tropics into the North Atlantic Ocean. Since the simultaneous pressure and echo soundings give the depth and the time of return of the echo, together they constitute a measurement of the speed of sound in sea water corresponding to known conditions of pressure, temperature and salinity. It is to be expected that when this wealth of material has been worked up an important contribution will be made to the knowledge of the speed of sound in sea water.[9]

TESTS OF THE TABLES OF HECK AND SERVICE BY PIANO WIRE AND ECHO SOUNDINGS BY THE U. S. COAST AND GEODETIC SURVEY.

Heck and Service checked [1] their tables against simultaneous piano wire and echo soundings on 44 stations occupied by the Survey Ship *Guide* on an oceanographic cruise. The temperature and salinity conditions on these 44 stations were fairly well known by means of serial temperature and salinity observations made by the *Guide*. They found an average percentage difference between the speeds from their tables, without the adiabatic corrections, and the measured speeds, of 0.2 of one per cent. The author has repeated this comparison, applying the adiabatic corrections, and has found that the effect of the corrections is to reduce the average percentage difference between the measured speeds and those from the

tables to *zero*, although as before there were individual discrepancies as great as 3.4 per cent. between measured and computed speeds.

Lieutenant E. W. Eickelberg, U. S. Coast and Geodetic Survey, in connection with the test of the fathometer that he installed on board the Survey Ship *Discoverer*, made a rather large number of simultaneous piano wire and echo soundings in the Pacific Ocean near the Hawaiian Islands. A considerable number of serial temperature observations were taken; also the salinity was fairly well known. He found that when he computed his echo soundings by speeds from the tables of Heck and Service, the echo sounding practically never differed from the piano wire sounding by more than one per cent., which included errors of observation in both soundings, errors of observation of temperature and the error of slope of the echo sounding.

DETERMINATION OF SOUND SPEEDS FOR ECHO SOUNDING IN THE U. S. COAST AND GEODETIC SURVEY.

Instructions for echo sounding in the U. S. Coast and Geodetic Survey require the hydrographer to take serial temperatures in the area to be surveyed, with the vertical interval such that the change of temperature between successive layers shall not exceed one degree Centigrade and with spacing of serial temperatures over the area such that the weighted mean temperatures from adjacent stations shall not differ by more than one degree Centigrade. These temperature observations are checked from time to time during a working season to detect any seasonal change should one occur that is of practical importance.

The author [10] has worked up simple procedure for the measurement of salinity of sea water: (1) by hydrometer; (2) by titration with silver nitrate with potassium chromate as indicator; and (3) by the dipping refractometer. Any of these methods can be used on board a vessel under way to give salinity, even in inexperienced hands, with an uncertainty not greater than 2 or 3 in the third significant figure. The hydrographer is required to make salinity measurements at such vertical intervals and with such spacing over the area that he will be sure of the second figure of salinity in any layer in any part of the area.

By means of the temperature and salinity data so obtained and the speed of sound tables of Heck and Service, the hydrographer can easily work up the values of speed of sound in convenient layers in the various sections of the area. The speed to be used in sounding to a given depth in a given section of the area is then the weighted mean of the layer speeds down to that depth.

DETERMINATION OF SOUND SPEEDS FOR RADIO-ACOUSTIC POSITION FINDING IN THE U. S. COAST AND GEODETIC SURVEY.

In the Coast and Geodetic Survey up to the present time, sound speeds for use in radio-acoustic position finding [11] have been determined almost exclusively by direct measurement. The ship, while within range of visibility of shore objects, fires a bomb in the water alongside and at the same time fixes its position by means of angles between shore objects measured on board the ship with sextants. The radio-acoustic apparatus measures the time of sound travel from the ship to the hydrophone at each of the shore stations. The positions of these hydrophones are plotted on the hydrographic sheet so that as soon as the ship's position has been plotted, the distance from the ship to each hydrophone can be scaled off. Thus two distances (usually only two stations are used) with the corresponding times of sound travel are obtained, which give two values of the speed of sound. It has been the practice of the Survey Ships in the past to use the mean of a large number of values of speed so measured during the season, for reducing and plotting all the radio-acoustic positions obtained by that ship during that season.

Since areas in which the ship's positions are fixed by the radio-acoustic method are usually sounded by the echo method, and since the temperature and salinity conditions in those areas would be therefore already determined as explained in the preceding section, it is the opinion of the writer that sound speeds for radio-acoustic position finding would be more accurately obtained from the tables of Heck and Service or of the British Admiralty rather than by direct measurement. The data presented in the next section, which is impartial, gives evidence that the probable errors of speeds taken from the tables would not be great, certainly no greater than

the errors inherent in the present practice. Furthermore, temperature and salinity conditions can be determined as far offshore as radio-acoustic positions are carried, while direct measurements of speed can be effected only within range of visibility of shore objects where generally the radio-acoustic method *will not be used;* the average physical conditions of the water over the ranges where the method *is used* will probably not be the same as those over the ranges where the speeds are measured.

TRANSMISSION OF SOUND IN RADIO-ACOUSTIC POSITION FINDING.

Early in 1925 the author had occasion to study speeds of sound measured as explained in the preceding section in 1924 by the *Guide* in the vicinity of Cape Blanco, Oregon, and to study the measured speeds in connection with temperatures measured by the *Guide* in the same area at about the same time for the Scripps Institution of Oceanography. The mean temperature over the straight line paths between bombs and hydrophones during the month of July was 11° C.; the salinity was 33 parts per thousand, very nearly. The mean measured value of speed was 1,473 meters per second. For the given conditions the tables of Heck and Service give a speed of 1,492 meters per second; *the discrepancy between this value and the measured value is considerably in excess of the combined possible errors of measured speed, measured temperature and the tables.* On the other hand, the *mean temperature between surface and bottom* over the area in which measurements of speed were made during July was 7° C.; the salinity was 33. The tables give for these conditions a speed of 1,475 meters per second, *which is in very fair agreement with the measured value, 1,473.*

The mean measured value of speed in October was 1,493 meters per second. The mean temperature from surface to bottom was 11° C.; the mean salinity was 33. For these conditions the tables give a speed of 1,491 meters per second, which also agrees very fairly with the measured value. Unfortunately no serial temperature observations were made during August or September.

This correspondence between speed of sound directly measured for horizontal transmission and the mean effective pressure,

temperature and salinity between surface and bottom over the range between bomb and hydrophone was independently discovered by the writer in the spring of 1925 and was announced to the Commanding Officer of the *Pioneer* through the Commanding Officer of the *Guide* in a letter written at San Pedro, California, on March 7, 1925.

The author at that time proposed (in the above-mentioned letter) the following hypothesis as to the mechanism of horizontal sound transmission, with which hypothesis, it is well to state frankly, many of his superior officers and associates disagree: that the sound energy from the bomb makes its way to the hydrophone principally by multiple reflections between surface and bottom*; whatever may precede it, the peak value of power received at the hydrophone, the peak that sets into operation the automatic transmitter [11] of the radio-acoustic apparatus, comes from bomb to hydrophone by way of all the horizontal layers of water between bomb and hydrophone; since the loss of energy by reflection increases as the incident and reflected wave fronts approach parallelism with the reflecting surface, the effective sound energy is propagated by very oblique reflections, so that the total length of path is not appreciably in excess of the distance measured along the surface from bomb to hydrophone; if the water between bomb and hydrophone is deep, fewer reflections and less loss of energy by reflection will occur than if the water is shoal, that is, a given quantity of sound energy released by a sound source can be transmitted practically to greater distances in deep water than in shoal water. In other words, the surface and bottom form a great two-walled speaking tube; as in any speaking tube if the walls are too close together so that the tube has too small a cross sectional area transmission will not be efficient. Upon this hypothesis it would be expected that sound could be transmitted to greater distances when the surface of the sea is smooth, other conditions being equal, than in rough weather; such seems to be the case. Likewise, the distance to which sound could be transmitted would depend upon the material and configuration of the bottom; the

* In shoal water, such as off North Carolina and Florida, evidently this must be the case because the straight line between bomb and hydrophone passes below the surface by a distance exceeding the depth of water.

author is not prepared to present evidence of the effect of the bottom material upon the transmission of sound in radio-acoustic position finding, but in the following are described two cases where it is believed that the failure of the radio-acoustic method can be attributed to a peculiar configuration of the bottom.

Professor Cole has, in this connection, reminded the writer of some early measurements of the speed of sound in air that were carried out in the water mains of Paris, where the speed was found to be a function of the diameter of the pipe, being greater for the larger pipes. This work was done by Regnault in 1862–63.[17] Regnault found also that the decrease of intensity with distance was greater, the less the diameter of the pipe. The writer would suggest that the two effects are probably closely related, for in sea water, at least, the speed increases with intensity, as pointed out in the last section of this dissertation. How could either effect be explained if transmission by multiple reflections between the walls be not assumed?

Dr. Earhart has reminded the author that the case of multiple reflections between surface and bottom is not quite analogous to the experiments of Regnault, because when the sound is reflected from the under surface of the water a change of phase of 180° occurs, where in the multiple reflections between the inner walls of the pipe no phase change occurs.

It had been found in the summer of 1924 that sound could not be transmitted appreciably across a submerged bank, steep on the seaward (bomb) side, located a few miles northwest from Cape Blanco, Oregon, although the crest of this bank was far below the straight line paths between bombs and hydrophones. This phenomenon was cited by the writer in his letter above mentioned in support of his hypothesis. For by his hypothesis a great part of the energy from the bomb would be reflected from the seaward side of the bank at nearly normal incidence with resulting great loss by reflection; in fact some of the energy would be reflected backward and wholly lost.

In like manner, it was found that no appreciable sound energy could be transmitted across Cortez Bank or Tanner Bank, off the coast of southern California, in the work of the *Guide* in the winter and spring of 1925, although the banks did

not intercept the straight line paths between bombs and hydrophones. These banks are extremely steep on the sides away from San Clemente Island, where the hydrophones were located.

Here Dr. Earhart suggests that if the theory of transmission proposed is correct and the effect on transmission from deep water to a bank is a fact, then the attenuation would be different according to whether the sound travels across the bank toward the shore or away from shore, and that this difference of attenuation might be capable of experimental verification.

In 1926 the *Guide* and *Pioneer*, working in adjacent areas north and south, respectively, of the mouth of the Columbia River, made a large number of measurements of the speed of sound in sea water for use in plotting the season's radio-acoustic positions. Unfortunately, not enough temperature and salinity data is available for the *Pioneer's* area to make her measurements of value for this study. The same is true of the *Guide's* area so far as measurements made in connection with her northern station (Westport, Washington) are concerned; but the area involved in measurements made in connection with her southern station at North Head, although the temperature and salinity data even here are inadequate, is fairly well represented by well-distributed temperature and salinity measurements made by the *Guide*. These serial observations yield a mean effective temperature from surface to bottom over the area covered by the measurements, of 6° C., and a corresponding salinity of 33 parts per thousand. The tables of Heck and Service give for these conditions a speed of 1,471 meters per second. The mean of the measured speeds was 1,469 meters per second. This very fair agreement is cited as further evidence in favor of the author's hypothesis as to the manner of transmission of the peak of power from bomb to hydrophone (giving due consideration to the fact that the temperature and salinity data are not adequate), because the temperature and salinity along the straight line path were approximately 13° C. and 33 parts per thousand, respectively, and the tables of Heck and Service for these conditions give a speed of 1,498 meters per second. The great discrepancy between this latter value and the mean measured value is far in

excess of the combined probable errors of the speed and temperature measurements and the speed tables.

It is evident that on the author's hypothesis the rate of decrease of intensity with increasing distance from the source will be less, and the range of a given hydrophone will be greater than on the assumption that the hydrophone is actuated solely by sound energy that follows the straight line path; for the intensity (on the author's hypothesis) will be more nearly proportional to the inverse first power than to the inverse square of distance.

The author wishes to state that he has advanced the above explanation merely as an hypothesis that seems consistent with such experimental data as are at hand. It does not appear to be inconsistent with any physical principles. It seems probable to the author, who has listened during several years to echoes from the ocean bottom, and who realizes that the bottom is a better reflector of sound, even at perpendicular incidence, than is generally supposed.

At the same time, the important thing in the preceding part of this section is not this hypothesis, but the experimentally verified correspondence of the speed of sound with the mean physical conditions between surface and bottom, and the effect of submerged banks upon the horizontal transmission of sound energy. The hypothesis may or may not be correct; the author will be ready to discard it when he is convinced that it is untenable, or when a more probable explanation comes to his attention. But the correspondence between speed and mean conditions has at least a considerable mass of experimental data in its support.

If the above hypothesis has no other virtue, it has justified its existence by the wealth of constructive criticism that it has evoked from the author's professors at the Ohio State University. Professor Cole has advanced an alternative explanation; Dr. F. C. Blake has introduced the author to Aigner's excellent treatise "Unterwasserschalltechnik," and Aigner verifies Professor Cole's explanation; Dr. R. F. Earhart has advanced a second alternative explanation. It is quite possible that after further reflection and calculation based upon these new ideas, the author may reject his multiple

reflection hypothesis altogether or at least modify it very radically.

Professor Cole has suggested independently that although the usual temperature gradient has the effect of refracting the direction of propagation downward (because the speed is greater in warm water than in cold), nevertheless in deep water the increase of speed with increasing pressure may well more than neutralize the temperature effect, so that the sound energy may follow a path through nearly all the layers between surface and bottom and yet be deflected upward toward the surface without reaching the bottom at all.

Aigner [20] has proved by calculation that the above explanation made independently by Professor Cole is feasible. His German is so excellent that the author is unwilling to spoil it by translation and therefore quotes it verbatim.

" . . . ist letztere (die Kompressibilitätskoeffizientenänderung) bei Wasser von 0° C. bei einer Druckzunahme auf 200 Atmosphären (corresponding to an increase of depth of about 1000 fathoms) ebenso groß wie bei einer Temperatursteigerung von 0° auf 20° C. Da aber diese beiden Effekte hinsichtlich der Schallgeschwindigkeitsänderungen einander entgegenarbeiten, falls die Temperaturschichtung anotherm ist, so folgt daraus, daß in diesem Falle bei einer durchschnittlichen Wassertiefe von 2 km eine Kompensation eintritt, somit auch im Sommer der schädliche Temperatureinfluß nicht zur Geltung kommt. In noch tieferen Gewässern findet bei gleicher Temperatur-Differenz un -Richtung sogar eine Ablenkung der Schallstrahlen gegen die Wasseroberfläche zu statt. Es ist daher zu erwarten, daß in Gewässern, in denen der schädliche Temperatureinfluß durch eine entsprechende Wassertiefe mindestens kompensiert wird, Reichweiten von einigen tausend Kilometern mit unverhältnismäßig kleinem Strahlungsleistungen zu erziehlen sind. Es entbehrt dabei die Ueberlegung nicht eines besonderen Reizes, daß eine Depesche über eine Strecke von 1,500 km ca. eine Viertelstunde benötigt, bis sich die akustische Energie von der Sendestation durch das wogende Weltmeer zur Empfangsstation durchgearbeitet hat. Leider liegen diesbezüglich bis heute keinerlei systematische Messungen im tiefen Ozean vor."

The author would suggest that when the source is below the region of high temperature gradient, as it can well be in radio-acoustic position finding, the effective range will be greater, according to Professor Cole's hypothesis as confirmed by Aigner, because then no downward refraction but rather upward refraction will occur in the early part of the travel.

Dr. R. F. Earhart rejects the author's multiple reflection hypothesis entirely. He makes an alternative suggestion as to the mechanism of transmission that has much to commend it, and which it seems well to include here. His suggestion is that as the wave advances the mechanical drag of the bottom upon the longitudinal vibrations of the particles "tips over" the waves much as water waves are tipped over and broken when they advance into the shoal water near the beach. As the waves are tipped over they are caused to strike the bottom and are absorbed, the effect being much the same as when sound is propagated against the wind in air. The effect will be relatively greater in shoal water than in deep, so that the effective range of a given source will be less in shoal water than in deep water, as is in accord with experience. The speed of propagation would be determined, so he states, by the mean effective physical conditions between surface and bottom, which is also in accord with experience.

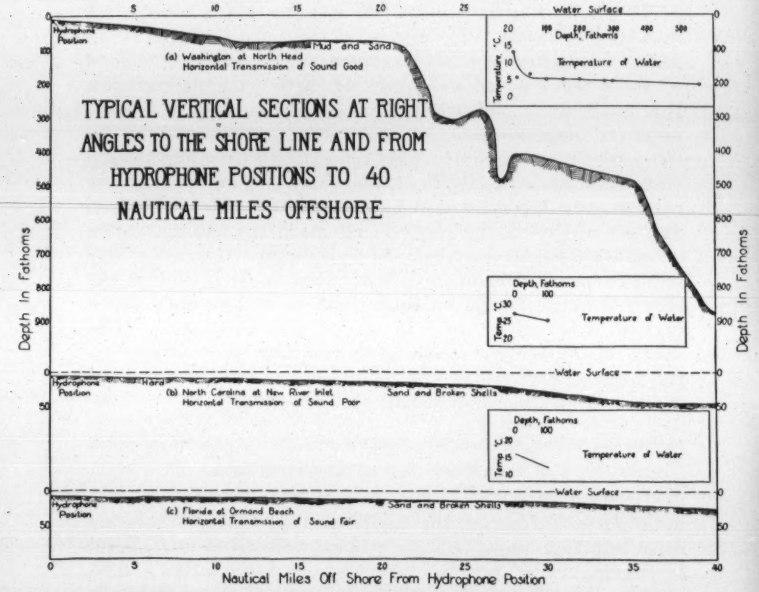
EXPERIENCE WITH RADIO-ACOUSTIC POSITION FINDING [11] IN VARIOUS REGIONS.

(*a*) In the Waters off Washington and Oregon.

In July, 1925, the writer planted hydrophones and laid hydrophone cables for the *Guide* at Port Orford, Hunter's Cove and Brookings, Oregon. These were the first shielded hydrophones used by the Coast and Geodetic Survey. The shielding was done under the direction of the writer and grew out of his study of the work of Brillié, as discussed in a later section of this dissertation. During the month of August, 1925, the *Guide* made a test run, steaming directly offshore from the Hunter's Cove station and firing a bomb in the water near the ship about once every half hour. A type of bomb designed by the writer, consisting of a hollow cast iron sphere of five inches inside diameter and one-half inch wall thickness, packed with loose TNT in which was imbedded a fulminate detonator with waterproof fuse, was found to be

most effective. Positions were obtained consistently with these bombs from the Port Orford and Hunter's Cove stations until the ship was more than two hundred (200) statute miles offshore and approximately that distance from each of the

FIG. 2.


TYPICAL VERTICAL SECTIONS AT RIGHT ANGLES TO THE SHORE LINE AND FROM HYDROPHONE POSITIONS TO 40 NAUTICAL MILES OFFSHORE
Water Surface
Hydrophone Position
(a) Washington at North Head
Horizontal Transmission of Sound Good
Mud and Sand
Depth, Fathoms
Temperature of Water
Temperature
Depth In Fathoms
(b) North Carolina at New River Inlet
Horizontal Transmission of Sound Poor
Hard
Sand and Broken Shells
(c) Florida at Ormond Beach
Horizontal Transmission of Sound Fair
Nautical Miles Off Shore From Hydrophone Position

two stations. At that distance the ship got out of range of the shore station radio transmitters; the limit of the range of sound transmission had not yet been reached. For some reason not well understood no appreciable energy from the bombs reached the hydrophone at Brookings. This remarkably successful run proved the practicability of the radio-acoustic method of controlling the momevents of a survey vessel on survey duty, at least in the waters off the Oregon and Washington coasts, and marked the beginning of the successful practical use of the method in those waters.

As an example of the practical use of radio-acoustic position finding in the waters off the coasts of Washington and Oregon, it may be stated that in 1926 the *Guide* surveyed the area between latitudes 46° 10′ N. and 47° 00′ N., from about 4 nautical miles offshore to about 70 nautical miles offshore. The positions of soundings in all parts of the area were fixed by the radio-acoustic method. Two shore stations were used, one near Westport, Washington, and one near North Head, Washington. It will be seen that the stations were located near the two inshore corners of the surveyed area; hence, when the ship was at either of the two offshore corners of the area, one of the two hydrophones was receiving sound energy from bombs fired from 75 to 80 nautical miles away. This may be described as good transmission.

The physical conditions in this area are shown in Fig. 2 (*a*), which represents a vertical section at right angles to the shore line from the hydrophone at North Head to 40 nautical miles offshore. The water temperatures are shown in the inset; the temperature gradient is seen to be rather great in the upper layers. The bottom materials probably are not very good reflectors of sound.

(*b*) In the Waters off North Carolina.

During the fall and winter of 1926–27 the *Lydonia* carried on experiments with radio-acoustic position finding off the coast of North Carolina between Capes Fear and Lookout to test the practicability of the method in those waters. The author took part in this work. Sound transmission was so poor that it was decided that the method was not economical in that area. The indications were that even with the hydrophone planted several miles offshore expectation that the hydrophone would receive sufficient energy from bombs fired more than 25 nautical miles away was not justified.

In addition to the poor transmission, the hydrophone circuit was very frequently disturbed by strong strays, especially in the late winter and early spring, believed to be caused by the sounds emitted by fish of the "grunt" family. Had the sound transmission been good enough to make it worth while, these strays probably could have been filtered out. The writer has experimented to some extent with an

electrical filter for similar strays off the Florida coast during the past winter, and the indications were that the filter would remove the strays almost entirely without seriously attenuating the energy from the bombs.

Fig. 2 (*b*) shows the physical conditions in the North Carolina area; it represents a vertical section at right angles to the shore line from the hydrophone at New River Inlet to 40 nautical miles offshore. The vertical scale is twice that in Fig. 2 (*a*). The temperature conditions of the water are shown in the inset; the temperature gradient is seen to be small. The bottom materials in this area are believed to form a surface that is favorable for the efficient reflection of sound energy.

(*c*) In the Waters off Florida.

During the past winter (1927–28) the *Lydonia* has carried on experiments with radio-acoustic position finding off the coast of Florida between St. Augustine and Cape Canaveral. The writer took part in these experiments. Sound transmission was found to be apparently somewhat better than off the North Carolina coast, although Fig. 2 (*c*) shows that the vertical section of the water at right angles to the shore line is not materially different from that in North Carolina, nor are the bottom materials believed to form any better reflecting surface than do those of North Carolina. Very few temperature data had been obtained up to the time of preparation of this dissertation; the inset shows the temperature conditions according to this inadequate data. Surprising as it may seem, the water is considerably colder than that in North Carolina. The conclusions from the Florida work were that with the hydrophone two nautical miles or more offshore, it is safe to expect the hydrophone to receive sound energy from bombs fired within a radius of 30 to 35 miles; expectations of a greater range did not appear to be justified.

DISCUSSION OF RADIO-ACOUSTIC EXPERIENCE.

The writer will not presume to decide why the transmission of sound in radio-acoustic work is good to excellent off the coasts of Washington and Oregon and poor to fair off the coasts of North Carolina and Florida. It will be well to consider what seem to be the probable factors affecting sound

transmission. One of the writer's associates, for whose scientific attainments and judgments he has very great respect, believes that within reasonable limits of depth of water the deciding factor is that of temperature gradient. If the gradient is great from surface to bottom, with the temperature decreasing with depth, the sound energy will be refracted downward and the associate mentioned believes that in such circumstances sound transmission will be poor. The writer agrees that such temperature conditions would be disadvantageous, but does not believe that temperature gradient is the deciding factor.

It is held by some of the writer's associates on the basis of experience that within reasonable limits of other conditions cold water will transmit the sound more effectively than warm water. This belief apparently is supported by the fact that transmission seemed to be better on the Florida coast than on the North Carolina coast, and also by the tests carried out by the *Guide* in Long Island Sound in November, 1923,[1, 13] in which tests the writer took part. Assuming equal temperature gradients the writer confesses himself at a loss to understand why water of low mean effective temperature should transmit sound better than water of higher mean effective temperature. As a matter of fact Aigner [21] has shown that the viscosity absorption loss of sound energy in sea water is decidedly less in warm water than in cold.

If in a given area transmission is better in winter than in summer the writer believes that the better transmission is due to a smaller temperature gradient (the surface temperatures more nearly equaling the bottom temperatures than in summer) rather than to a lower mean effective temperature.

It should be stated that many more tests were made with the hydrophone two miles or more offshore in Florida than in North Carolina, where all such experiments were discouraged by the strays attributed to the "grunts." The author considers it quite possible that if the tests were carried out in North Carolina during a time of year when the "grunts" were not active and with the hydrophone two miles or more offshore, just as good results might be obtained as in Florida.

It is significant that in North Carolina and Florida the hydrophone had to be placed about two miles or more offshore

to get the maximum range. In Florida, with the hydrophone one-half nautical mile offshore the range was about five miles; when it was 1.45 nautical miles offshore its range was 20 to 25 miles; when it was 2.1 nautical miles offshore its range was about 35 miles; when it was 10 nautical miles offshore its range was no greater than at 2.1 miles off. The experience in North Carolina was similar in this respect. On the Washington and Oregon coasts, however, in general no such effect was noted; one of the best stations, that at Port Orford, Oregon, (see account above of 200-mile run) had the hydrophone planted about 200 yards offshore.

Some of the associates of the writer hold that the amount of solid matter in suspension in the water is an important factor in sound transmission, transmission being poor (they state) when there is much suspended matter. The author has no data on the relative amounts of suspended matter in the waters off Washington-Oregon, North Carolina and Florida.

The fact remains that the transmission off either Florida or North Carolina is not nearly so good as off Washington and Oregon. The writer admits that a considerable temperature gradient, with temperature decreasing from surface to bottom, is probably unfavorable for good horizontal sound transmission. He is not ready to admit that sound is transmitted more effectively in cold water than in warm, with equal gradients. Nor is he ready to admit that the amount of suspended solid matter in the water, within reasonable limits, is an important factor in sound transmission. Granting that the surface and bottom in North Carolina and Florida are probably better reflectors than those in Washington and Oregon, nevertheless on the basis of his hypothesis as to the manner of sound transmission in radio-acoustic work, the author believes that the sound transmission is better off the Washington and Oregon coasts principally because the bottom slopes off more rapidly from the shore line to seaward so that the average depth of water between bomb and hydrophone is always considerably greater than is the case off North Carolina and Florida. In this connection the writer will quote from his hypothesis as to the manner of sound transmission as stated earlier in this dissertation. "If the water between bomb and hydrophone is deep, fewer reflections and less loss

of energy by reflection will occur than if the water is shoal, that is, a given quantity of sound energy released by a sound source can be transmitted practically to greater distances in deep water than in shoal water."

The author and his associates are open minded in the matter and will welcome suggestions from physicists and others as to the probably important factors affecting the horizontal transmission of sound through sea water. (See page 791.)

PHENOMENA OBSERVED IN CONNECTION WITH RADIO-ACOUSTIC POSITION FINDING AND ECHO SOUNDING.

Shielding of the Hydrophone.

In the first three seasons (winter of 1924, summer and fall of 1924, winter of 1924–25) of radio-acoustic work in the Coast and Geodetic Survey, the hydrophones were mounted so as to be fully exposed to the water and the hydrophone circuit was at most times continually being disturbed by strays of moderate intensity. The writer took part in all of this work and taxed his ingenuity to the utmost in his efforts to eliminate this trouble, which was so serious that it raised serious doubts as to the practical value of the radio-acoustic method.

These strays, or "parasite noises," received the name of "water noises," because some of the associates of the writer believed that they were caused by the roar of the surf on the beach. The writer never held this opinion, but believed that the strays were due to subsurface water currents flowing over the exposed hydrophone; these currents, in addition to the action of the water itself, perhaps cause sand, bits of shell, etc., to strike the hydrophone. Also, the hydrophone current had been observed to "breathe," i.e., increase and decrease slowly in value, which the writer attributed to the periodic changes in the hydrostatic pressure at the hydrophone caused by the passage of surface waves.

It was suggested by Dr. E. A. Eckhardt that the hydrophone might well be shielded by enclosing it in a perforated metal case. This was tried and effected no appreciable improvement.

In reading "Mechanical Properties of Fluids," by Drysdale and others, the author came upon an account of the work of Brillié, in which the latter had found the acoustic resistance

of certain kinds of wood to be nearly equal to that of sea water. It occurred then to the writer that if the hydrophone be enclosed in a fairly large, watertight wooden case, as for example a keg, filled with sea water, sound would pass through the wood and reach the hydrophone without attenuation, while the hydrophone would be completely shielded from mechanical disturbances. Some preliminary experiments were conducted by the writer, assisted by Almon M. Vincent, Chief Wireless Operator of the *Guide*. These experiments, in which two matched hydrophones were used, one exposed and one sealed in a keg full of sea water, gave very encouraging results. The shielded hydrophone was quite as sensitive to *sound* as the exposed one; the exposed one was subject to strays as usual, while the shielded one was almost entirely free from such disturbances. At the Port Orford station mentioned above in connection with the 200-mile test run of August, 1925, a single hydrophone was used, sealed in the keg used in the preliminary experiments. At Hunter's Cove three hydrophones in parallel were sealed into an oak box made for the purpose. In the box made for the hydrophone at Brookings several one-half-inch holes were bored; it is perhaps significant that the hydrophone circuit at that station was disturbed by strays as usual.

Since that time all the radio-acoustic hydrophones used by the Coast and Geodetic Survey have been sealed into watertight wooden cases filled with sea water, with very beneficial results on the Pacific Coast. On the coast of North Carolina the hydrophone cases did not eliminate the bad strays, because these strays were *sound* and not mere mechanical disturbances.

The writer has made a study of Brillié's original paper.[14] It is shown that where sound passes successively through three media of acoustic resistances n, n_1, n_2, then if

$$r_1 = \frac{n_1}{n} \quad \text{and} \quad r_2 = \frac{n_2}{n_1},$$

$$(1) \qquad \frac{\text{Energy transmitted}}{\text{Energy incident}} = \frac{4r_1r_2}{(r_1r_2+1)^2} \times \frac{1}{1-\sin^2 a_1 \dfrac{(r_1^2-1)(r_2^2-1)}{(r_1r_2+1)^2}},$$

where

$$a_1 = 2\pi \frac{I_1}{L_1},$$

I_1 being the thickness of the second medium.

If $n = n_1 = n_2$ as when the first and third media are sea water and the second is a material having the same acoustic resistance as sea water, the expression on the right becomes equal to unity and the sound is transmitted without attenuation.

If a_1 is nearly zero, i.e., if the thickness of the second medium is sufficiently small relative to the wave-length of the sound, then, as Brillié points out, we may set $\sin^2 a_1$ equal to zero, and we have

$$(2) \qquad \frac{\text{Energy transmitted}}{\text{Energy incident}} = \frac{4r_1r_2}{(r_1r_2 + 1)^2} \frac{4\frac{n_2}{n}}{\left(\frac{n_2}{n} + 1\right)^2},$$

which is as though the second medium did not exist, i.e., we need not be so careful to have its acoustic resistance near to that of sea water.

It may be stated as a matter of experience that sound from TNT bombs fired under water passes without appreciable attenuation through wooden cases having wall thickness of from one to two inches of any available hard wood; the wave-length of the sound is not definite but probably ranges from about fifteen feet to greater lengths. On the other hand, Dr. Herbert Grove Dorsey, Senior Electrical Engineer of the Coast and Geodetic Survey, found that wooden planks four inches thick were scarcely penetrable by sound of wave-length about five feet.

As Brillié points out, if the thickness l_1 of the second medium is equal to an exact multiple of half wave-lengths, then $\sin^2 a_1$ will be equal to zero and Eq. (2) will apply. It has occurred to the writer that this principle may serve as a means of shielding ultra-sonic receivers from "parasite noises" or strays, where these are due to mechanical disturbances; the wave-lengths of ultra-sonic energy range from about one-twentieth to one-sixth of a foot, i.e., from a little more than

one-half inch to about two inches. In the *Hydrographic Review*, Vol. IV, No. 2, November, 1927, is given an account of a considerable amount of trouble being experienced in such a receiver due to "parasite noises." The writer would suggest that if it were feasible to shield this receiver by a case of which the wall thickness is very nearly an exact multiple of the wave-length, the "parasite noises," if due to mechanical causes, might be eliminated without appreciable attenuation of the ultra-sonic energy.

RELATIVE ATTENUATION WITH DISTANCE OF SOUNDS OF GREAT AND OF SMALL AMPLITUDES.

Stokes, Rayleigh and Hart have shown [15] that in the transmission of sound energy through air, sounds of great amplitude have a greater relative decrease of intensity with increasing distance from the source than do sounds of small amplitude. Experience with radio-acoustic position finding has given qualitative evidence of the same effect in sea water, as might be expected. For example, if the ship is within ten or fifteen miles of a given hydrophone a no. 8 blasting cap fired in the water near the ship will usually send plenty of energy to that hydrophone to trip the apparatus; apparently a five-inch, cast iron, TNT filled bomb, of the type described earlier in this dissertation will not deliver more than about twice as much power as the blasting cap to the given hydrophone. The indications are that there will certainly be a limit to the range of a given hydrophone that cannot be increased, no matter how large or powerful the source of sound; this is probably because the more powerful the source, the more rapidly does the amplitude of the waves originating from that source decrease with increasing distance from the source.

VARIATION OF SPEED WITH INTENSITY.

Early in 1925, the writer, under the direction of Lieutenant Commander Thomas J. Maher, U. S. Coast and Geodetic Survey, Commanding Officer of the *Guide*, experimented with recording on a chronograph tape the times of explosion of blasting caps fired just beneath the surface of the water and the times of return of the echoes from the bottom, as a means of measuring depth roughly in fairly deep water. In 200 to

400 fathoms of water the method gave rather good results. Several echoes were recorded from each explosion. *The interval between the explosion and the return of the first echo was roughly only about half of the intervals between successive echoes*, presumably because of the great intensity of the wave before the first reflection from the bottom. The intervals between successive echoes apparently were equal and gave the correct depth to a fair approximation.

This recalls the work of Threlfall and Adair.[19] Glazebrook [18] gives so good an account of this work that it seems well to quote him here verbatim.

"Threlfall and Adair published in 1889 their experiments on the speeds of sound-waves from explosions under water in Port Jackson harbour, Australia. Charges of gun cotton were used; the firing was electrical and gave a signal on a chronograph, on which also was recorded the instant when the sound reached an india rubber diaphragm immersed at the far station 150 meters of more distant. The normal speed for feeble sounds in water was calculated to be about 1,500 meters per second; the observed speed of the explosion wave from 9 oz. of gun cotton was 1,732 meters per second and from 64 oz. of gun cotton was 2.013 meters per second."

Reference has already been made to the work of Regnault, which indicated a similar effect in air (p. 20).

APPENDIX. A BRIEF DISCUSSION OF METHODS IN USE IN THE U. S. COAST AND GEODETIC SURVEY FOR THE MEASUREMENTS OF DEPTH OF WATER.

In comparatively rare cases very shoal depths are measured with poles. This method is necessarily limited to water that is not more than about 2 fathoms deep.

Depths of 15 to 20 fathoms and less can be sounded economically by means of the hand lead and line. The ship sounds to as near shore as considerations of safety will permit; the areas nearer shore than this are surveyed by power launches or pulling boats. When the hand lead and line is used by the ship she runs continuously at a speed of about 6 knots. Power launches and pulling boats sounding with hand lead and line operate at somewhat lower speeds. Soundings are taken at intervals of about a minute or less.

"Trolley sounding" is similar to hand lead sounding but can be carried economically to depths of about 30 or 35 fathoms. The lead is dropped from forward and the line becomes vertical with the lead on the bottom to the leadsman stationed aft. As in hand lead work the leadsman reads off the depth from marks on the line. The lead is hauled in ready to drop from forward again by a power reel located forward. As in hand lead sounding the ship runs continuously at a speed of about 6 knots; soundings are taken at intervals of about 1½ minutes.

"Wire soundings" are carried out by means of a heavy lead (in deep water a detachable "shot") lowered by stranded or solid steel piano wire wound on a drum. The wire passes around a carefully calibrated sheave, which measures the number of fathoms of wire run out with considerable precision. The wire is reeled in by power on board ship and by hand on board a small boat. The method is applicable to any depth. The ship or boat must be kept "dead in the water" during a wire sounding in order to keep the wire vertical. Since the development of acoustic sounding methods, wire soundings are used principally as checks on the accuracy of acoustic soundings and pressure tube soundings.

Pressure tube soundings are applicable to depths from about 15 fathoms to about 80 fathoms. The Rude-Fischer tube is used, in which enough water is forced into the tube through a capillary opening in the cap to compress the air in the tube to equilibrium with the hydrostatic pressure outside. The capillary opening becomes water sealed so that neither the air nor the entrapped water can escape. The quantity of water forced in is a measure of the depth to which the tube has been lowered. During pressure tube sounding the ship runs continuously at a speed of about 6 knots and soundings are taken at intervals of about one or two minutes. The wire sounding machine is used in pressure tube sounding, a short length of cotton or manila line is placed between the lead and the end of the wire, and the tube is secured to this line just above the lead. Acoustic sounding with the "fathometer" is more or less superseding pressure tube work.

The "fathometer" equipment, manufactured by the Submarine Signal Corporation, consists of: (1) an electrically

driven oscillator with its diaphragm outside the skin of the ship below the water line, for generating short powerful sound impulses; (2) a microphone mounted in a tank full of water in contact with the inside of the ship's plating below the water line, and connected through a filter and amplifier to a neon tube and head phones, for receiving echoes of the oscillator signals from the ocean bottom; and (3) a device for measuring the time of return of the echo, consisting of a disk rotating at known, uniform speed behind a translucent dial graduated in fathoms, about an axis through its center perpendicular to its plane, and having two radial slits with the neon tube behind one and a fixed white light behind the other. The oscillator is made to sound when the neon tube slit and the white light slit are in line with the zeros of their respective scales on the translucent dial. In depths less than about 150 or 200 fathoms the neon tube flashes when the return echo is received, and since oscillator signals are sounded at intervals of ¼ second the result is a flickering luminous red indicator pointing out the depth of water on the dial. In deep water the disk carrying the slits is made to rotate more slowly, the oscillator signals are made to sound at greater intervals, and it is necessary to note the position of the white slit on the dial when the echo is heard in the phones. With a large oscillator this "white light method" is applicable to the greatest known depths. The "red light method" is not yet used for survey work in depths less than about 15 fathoms.

The "sonic depth finder," according to the experience of the writer, is applicable for survey work in depths from about 80 fathoms to the greatest known depths. The method of producing the sound is exactly that used in the fathometer and the method of receiving the echo is essentially the same. The distinctive feature, developed by the U. S. Navy, is the method of measuring the time of return of the echo. The oscillator signals are sounded at regular, adjustable, measurable intervals. The length of this interval is adjusted until the echo returns at the same instant as the first, second or third succeeding oscillator signal is sounded. The time of return of the echo is then equal to, or a known whole multiple of, the interval between oscillator signals. The sonic depth finder is being superseded on board the ships of the U. S. Coast and Geodetic Survey by the fathometer.

Soundings taken by any method are all reduced to the same stage of the tide, usually mean low water or mean lower low water, and as stated elsewhere in this dissertation echo soundings are reduced to the speed of sound corresponding to the physical conditions of the water where and when the soundings are taken.

In some areas obstructions of small extent are likely to occur, such as pinnacle rocks for example, that are especially dangerous to navigation but are not likely to be discovered by the methods above discussed. In such areas the above methods are supplemented by dragging operations with the wire drag or sweep.[16]

The author wishes to express his appreciation to Commander W. E. Parker, Chief of the Division of Hydrography and Topography of the Coast and Geodetic Survey, and to Lieutenant Commanders Thomas J. Maher and R. F. Luce, and Lieutenant K. T. Adams, Commanding Officers of the Survey Ships *Guide*, *Pioneer* and *Lydonia*, respectively, who as the author's superior officers have afforded him many opportunities to carry on investigations in the subject of this paper. Also, it is a pleasure to express gratitude to Dr. T. Wayland Vaughan for temperature and salinity data furnished by the Scripps Institution of Oceanography for the ocean waters off the coasts of Washington and Oregon. Finally, the author acknowledges gratefully the help given him by Mr. Roswell C. Bolstad and Mr. Harold J. Oliver, Deck Officers in the Coast and Geodetic Survey, who inked and lettered the illustrations.

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Fighting Fires and Preventing Dust Explosions with Flue Gas —U. S. Department of Agriculture, Press Service. The use of inert gas, or flue gas, piped from the furnaces of manufacturing plants for use in preventing fires and resultant dust explosions in grinding equipment should be seriously considered wherever the hazard exists, according to engineers of the Bureau of Chemistry and Soils.

Of 30 explosions occurring in feed-grinding plants during a 20-year period, 18 originated in the grinding equipment where it was impossible to prevent the formation of dust clouds or to eliminate sources of ignition. Experimental work by the department engineers has shown that it is practicable to use inert gas for flooding the inclosures of the grinding equipment and diluting the oxygen content to such a point that fires or explosions can not take place. The results of the investigation are described in Technical Bulletin 74-T, "The Value of Inert Gas as a Preventive of Dust Explosions in Grinding Equipment," recently issued by the department.

Although the investigations were conducted in feed-grinding equipment, the results suggest many other possible uses for inert gas as a fire preventive. A modern development of this fire-extinguishing principle is the storage of compressed inert gas in tanks with distributing pipes which lead to the most likely sources of fire and quick-acting valves to release the gas. Such equipment has been used on ships and also in factories. A portable extinguisher consisting of a small tank of carbon dioxide under pressure has recently been placed on the market.

Inert gas, especially carbon dioxide, has many advantages over other fire-fighting mediums since it will not injure metals, fabrics, food products, or other perishable materials. Neither does it freeze or deteriorate, and as it does not conduct electricity it can be used to extinguish fires in electrical equipment. Carbon dioxide leaves no residue, which is a distinct advantage, since frequently the residue or damage caused by the extinguishing medium constitutes a greater part of the total loss. These advantages indicate a promising field for inert gas as a fire-fighting medium as well as for explosion prevention.

THE TIME LAG OF THE SPARK GAP.

BY

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IT is well known [1] that under certain conditions a spark gap in air can be overvolted for a considerable time without a disruptive discharge taking place between its terminals, where by overvoltage is meant any voltage above the least voltage that will produce a disruptive discharge when applied for an indefinite period. If, however, ultraviolet light is allowed to fall upon the electrodes or if a sufficient number of ions are present in the gap, the discharge takes place immediately upon application of the overvoltage.[1,2] This time of overvoltage or, as it is usually called, the time lag of the spark gap is shortened by increasing the magnitude of the overvoltage and becomes extremely short when steep, high voltage wave-fronts strike the gap. Pedersen[2] has observed time lags of sphere gaps in air as short as 10^{-7} sec. and in needle gaps even 5.6×10^{-8} sec., while McEachron and Wade,[3] using the cathode ray oscillograph found the time lag of the needle gap to be of the order of magnitude of one micro second. A large number of observations with varying amounts of overvoltage have been made by various observers under a wide variety of experimental conditions but most of their results have not been beyond criticism [4] due to the unknown magnitude and distribution of the space charge formed as the result of the large difference in mobilities of positive and negative ions.

In the present work a new method of measuring the time lag is described and some of the lags for sparks in air at atmospheric pressure have been recorded. The field strength used ranged approximately from 60,000 volts per cm. to

[1] Sir J. J. Thomson, "Conduction of Electricity through Gases," Cambridge University Press, 2d Edition, p. 431.

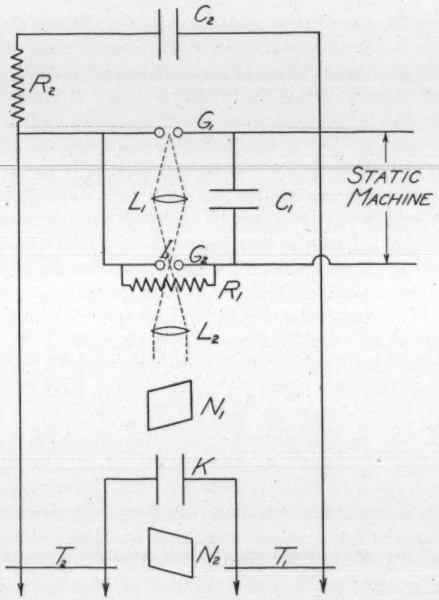
[2] P. O. Pedersen, *Ann. Der Physik*, 71, 317, 1923.

[3] McEachron and Wade, *General Electric Review*, 28, 622, 1925.

[4] Loeb, JOURNAL OF THE FRANKLIN INST., 205, 305, 1928.

400,000 volts per cm. with as steep wave-fronts as could be obtained.[5] The method here used not only enables one to measure very short time lags which occur with high field strengths but the measuring device itself does not affect the results. This latter feature, as will be shown later, is of extreme importance if the results are to be of any value.

FIG. 1



The measuring instrument is a modification of that previously used [6] to measure the order of appearance of spectrum lines in sparks and condensed discharges and can best be described by referring to Fig. 1. The condenser, C_1, of .0015 microfarad capacity is slowly charged by a static machine.

[5] Lawrence and Beams, *Phys. Rev.*, 32, 478, 1928.
[6] Beams, *Phys. Rev.*, 28, 475, 1926.

This impresses a voltage across G_1 and G_2, which are two spark gaps in series but, due to the electrolytic resistance, R_1, of 10^5 ohms and comparatively small charging current, practically all of the potential is impressed across G_1. As the voltage across G_1 is slowly raised, a point is reached where the spark discharge takes place. This overvolts G_2, provided G_2 is smaller than G_1, since the steep wave-front cannot pass R_1 and the voltage wave probably is doubled by reflection at G_2. After a certain time (which is to be measured in these experiments) the gap G_2 discharges, the voltage across C_1 falls to zero and the process is repeated. If the time lag in G_2 is fairly long, as in some of the experiments, the spark discharge in G_1 stops before G_2 discharges and sets up harmful oscillations. Therefore a condenser C_2 of .001 microfarad capacity with 150 ohms in its leads was attached in parallel with G_1 to keep it ionized until the spark at G_2 started. Light from G_1 was brought to focus by lens L_1 at the point I_1, made parallel by the lens L_2 and passed through a Kerr cell containing CS_2 which was placed between crossed Nicols. The point I_1 is not in the gap G_2 but above it. Light from G_2 was raised almost to the same horizontal plane of I_1 by means of a right angled prism (not shown in the figure), made parallel by L_2 and then passed through the Nicols and Kerr cell so that in the field of view as seen through N_2, G_1 appeared just above G_2. The leads to the Kerr cell K were attached by copper wires T_1T_2 to opposite sides of G_1, these wires were of variable length and free as possible from loops and other influences that tend to increase their inductance.

As the potential builds up relatively slowly across G_1 it is also applied across K which becomes doubly refracting and light can pass N_2. If then G_1 discharges it has been found that none of its visible light, at least, passes N_2 provided of course that T_1T_2 are as short as possible and the intensity of the field in K is not too great. It is only when the field producing the double refraction is of such a value that the amount of light passing N_2 varies approximately as the fourth power of the field strength that the quick cut-off can be attained. By increasing symmetrically the length of T_1T_2 the light from G_1 first appears and then as T_1T_2 are still further increased the light from G_2 appears. If the length of wire

from G_1 to G_2 is equal to the difference in the light paths of G_1 to K and G_2 to K then the length of wire added to each lead from the first appearance of the light of G_1 until the first appearance of that of G_2 divided by the velocity of the electric impulse along the wire, is equal to the time lag of G_2. This assumes of course that the rate of increase of the light in G_2 is the same as in G_1, which is true to a very high degree of approximation since both gaps are in air and the amount of energy fed into G_1 by C_2 is very small during the initial stages of the discharge.

It should also be pointed out that it is necessary to observe the first appearance of the air lines in each spark because the fall of potential is almost coincident with the appearance of the air lines while the time between the appearance of the air lines and the metallic lines in single sparks depends somewhat upon the energy available for evaporation of the metal. The times between the appearance of the metal lines however are quite constant. The light from G_1 was carefully screened from G_2 and an air blast was directed between the terminals of G_2 so that the ions were removed between sparks. Care was taken to reduce the capacity of G_2 to a minimum by making the binding posts as small and as far apart as possible.

Since the time lags to be measured might be a function of such things as the steepness of the voltage wave which strikes it or the capacity of the gap these factors were investigated first. With, for example, 2 cm. brass balls in G_1 and G_2 and with those in G_1 3.5 mm. apart and those in G_2 2 mm. apart and the least inductance possible between G_1 and G_2, the time lag of G_2 was between 3 and 5×10^{-8} sec. Capacity was then added in parallel with G_2. A value of .00005 microfarad made the time lag greater than 10^{-7} sec. which with the particular arrangement used was the maximum lag that could be measured. This capacity was then removed and a few turns of wire added between G_1 and G_2 with another resultant increase in time lag. These observations serve to emphasize how important it is in this kind of work to reduce inductance and capacity to a minimum and suggests possible sources of error in other methods such as the capacity of the deflecting plates of the cathode ray oscillograph or large binding posts of the spark gap itself.

TABLE I.

For 2 cm. Brass Spheres in both G_1 and G_2.

Width of G_1 mm.	Width of G_2 mm.	Max. Time Lag 10^{-8} sec.	Minimum Time Lag 10^{-8} sec.
3.45	2.4	8.6	3.0
3.45	2.0	5.0	2.5
3.45	1.0	2.5	1.5

For Needle Gap, Radius of Curvature of .1 mm.

Width of G_1 mm.	Width of G_2 mm.	Max. Time Lag 10^{-8} sec.	Minimum Time Lag 10^{-8} sec.
3.45	7.5	10+	5.7
3.45	5.5	10	2.3
3.45	4.0	2.0	1.3
3.45	3.0	1.0	1.0−

Table I shows a typical set of observations for 2 cm. brass spheres in both G_1 and G_2 and when needles were substituted for the 2 cm. balls in G_2. It will be observed that as the gap G_2 is reduced and, therefore the voltage gradient raised, the time lag is decreased. It will also be noted that the time lag, especially at the lower field strengths, is not a definite magnitude but varies over a considerable range of values and in the needle gap the variation is greater than in the ball gap. When the field strength is increased the time lags become more definite and for the highest field strength used they become practically constant. This erratic behavior was at first thought to be due to factors in the circuit but a long series of tests and observations showed pretty definitely that the erratic behavior was not experimental error but the true nature of the spark lag itself.

It has long been known that in air at room temperature there is always a certain number of positive and negative ions continually formed by various natural agencies such as cosmic rays or radiations from radioactive materials. The electron when set free soon attaches itself to a molecule, or group of molecules, of oxygen or to the molecules of some electronegative vapor that is always present unless the air is purified with considerable care. The positive ion wanders around until it picks up an electron which may either be free or part of a

negative ion. The number of ions usually present at any time is relatively small and distributed at random. The time lag of the gap here measured is then merely the time required for these ions under the impressed field to ionize the gap sufficiently for its resistance to drop to a small value.

In most of these experiments, since the voltage doubles at reflection and no special care was taken to insure clean smooth electrodes, the maximum field strength always reached the order of magnitude of 100,000 volts per cm. in some part of the gap. In these high fields an ion can reach a velocity several times the thermal velocity if allowance is made for the fact that a few of the free paths are longer than the mean. The negative ion therefore probably loses its electron in the first few collisions. This free electron is then in a position to readily ionize the gas and the discharge is started. The positive ion, with these high fields also contributes to the ionization and is especially effective in producing electrons near the cathode. The mobility of the positive ion is about 10^{-4} that of the electron. This effects a distribution of space charge which is very important in the fall of potential across the gap.

If we adopt the above rather crude picture of the phenomena taking place in the gap during the initial stages of the discharge, the erratic behavior of the lag is explained. In the case of both the sphere and the needle gap the field is not uniform over the whole volume between the electrodes and the ions are distributed at random. The rate of increase of ions is therefore not the same in different sparks which accounts for the fluctuations observed in the preceding experiments. In the needle gap although the field is very high near the point it drops very rapidly as the distance from the point is increased so that over the greater part of the gap the field strength is less than in the sphere gap. This should account for the greater fluctuations observed in the needle gap than in the ball gap. It would also explain in a qualitative way the observation that the fluctuations become less with increased voltage (decreasing width of gap). However it is difficult to see how the fluctuations can be reduced so much with the increase of voltage gradient and reduction of the size of gap alone.

It is now generally believed that there is a dense adsorbed

layer of molecules that covers the surface of electrodes in air. This idea was first proposed by Zeleny [7] to explain the discharge from pointed conductors and has since been used to interpret many phenomena in connection with the spark discharge. The molecular film may complicate the beginning of the discharge by offering a virtual resistance to positive ions that are formed near the cathode, thus rendering them less effective in ejecting electrons from the cathode until a critical velocity of the ion is reached. This may account, in part, for the short lags as well as the absence of fluctuations with high field strengths. However, from previous experiments on the nature of this film, one should expect the positeld ions to be able to puncture the molecular film at a lower fiive strength than that here used. On the other hand this film may make it easier for electrons to be "pulled out" of the cathode by the electric field than when the cathode is outgassed and in a vacuum. If this were true it could explain the very short lags and absence of fluctuations observed with high field strengths.

The writer is very much indebted to Professors L. G. Hoxton and C. M. Sparrow for many helpful discussions, to Mr. J. C. Street for taking some of the observations and to Mr. A. J. Weed, instrument maker, for constructing part of the apparatus.

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[7] J. Zeleny, *Phys. Rev.*, 3, 69, 1914. J. Zeleny, *Phys. Rev.*, 16, 102, 1920.

Chemical Warfare at Sea. LIEUT. HAROLD W. NORTHCUTT of the U. S. Navy (*Chemical Warfare*, 1928, *14*, 374–378) discusses chemical warfare and the ship of the line or battleship. The ship will not attempt to project gas. Its main battery must be used for the immediate destruction of enemy vessels by means of high explosive shells. The secondary battery and the anti-aircraft battery are required, respectively, to repel torpedo attack by destroyers and attack by airplanes; the time element prevents their use for offensive chemical warfare; also, chemicals are of little use against airplanes. The airplanes carried by battleships are intended for observation purposes and fire control, not for the projection of chemicals. Chemical torpedoes, as distinguished from heavy explosive torpedoes, have little value as offensive weapons.

From the viewpoint of defense against chemicals, should they be used by the enemy, gas masks and a properly designed ventilating system suffice to protect from gas shells, and toxic and obscuring smoke screens. No additional defense is required against chemical torpedoes. The only probable method of attack by gas is by planes from aircraft carriers, should the enemy have control of the air and succeed in avoiding the fire of the anti-aircraft battery. Smokes and toxic chemicals may then be dropped in bombs, or the chemicals may be sprayed from the plane. The defense against such an attack is a gas alarm, protective clothing, gas masks, and control of the ventilating and air-purifying and cooling systems to prevent the transmission of the gases through the ship. Additional armor protection is not required.

J. S. H.

Viscosity of Milk. GEORGE MONROE BATEMAN and PAUL FRANCIS SHARP of Cornell University (*Jour. Agric. Research*, 1928, *36*, 647–674) have studied the viscosity of milk. The viscosity may be influenced by various factors, such as clumping of the fat globules, mechanical agitation, homogenization, pasteurization, freezing and thawing, age of the sample, and chemical composition of the total solids. The viscosity of a sample of milk does not necessarily indicate accurately the total solids content, except possibly for very restricted groups of samples; and the viscosity determination alone can not be used as a test for small amounts of added water.

J. S. H.

QUENCHING OF MERCURY RESONANCE RADIATION AND ITS RELATION TO REACTIONS SENSITIZED BY EXCITED MERCURY ATOMS.

BY

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IT has been shown that certain gaseous reactions proceed in the presence of optically excited mercury atoms which otherwise, under similar conditions of temperature and pressure, do not take place at all. Thus Cario and Franck [1] have shown that if a mixture of hydrogen and mercury vapor be placed in a quartz tube in the presence of copper oxide and radiated with light from a cooled quartz mercury arc a decrease in pressure occurs, corresponding to a reaction of the hydrogen with the copper oxide. On the other hand, if either one of the constituents hydrogen or mercury vapor is absent, or if all three constituents are present and the mercury arc is run hot, so that the center of the 2537 Å. line is reversed, the reaction does not proceed. A great number of other reactions have been shown to proceed under similar circumstances. Thus hydrogen may be made to react with oxygen,[2] ethylene, carbon monoxide and nitrous oxide [3] at room temperature; also ozone may be formed from oxygen in the presence of excited mercury atoms; [4] and ammonia [5] may be decomposed under similar circumstances. The first step in any of these reactions is obviously the absorption of the 2537 Å. resonance line of mercury by the mercury atoms in the mixture, causing them to be raised to the 2^3P_1 state, having 4.9 volts energy. These reactions have been called *sensitized reactions*, since the process is somewhat analogous to the sensitizing of photographic plates.

[1] G. Cario and J. Franck, *Zs. f. Phys.*, **11**, 161 (1922).
[2] R. G. Dickinson, *Proc. Nat. Acad. Sci.*, **10**, 409 (1924).
[3] H. S. Taylor and A. L. Marshall, *J. Phys. Chem.*, **29**, 1140 (1925).
[4] R. G. Dickinson and M. S. Sherrill, *Proc. Nat. Acad. Sci.*, **12**, 175 (1926).
[5] R. G. Dickinson and A. C. G. Mitchell, ibid., **12**, 692 (1926).

It has generally been assumed that all of the activational processes occurring in these reactions take place in the gas phase and that none of these steps takes place on the walls of the vessel. Recently, however, it has been suggested by Zemansky,[6] on theoretical grounds, that all sensitized reactions are catalyzed by the wall of the reaction tube nearest the incoming light.

As far as the present writer is aware there are no direct experiments on reactions sensitized by mercury vapor in which the effect of varying the size and shape of the front wall of the reaction tube has been investigated. Indeed there are grave difficulties involved in carrying out such an experiment. However difficult the experiment, it would, as Zemansky suggests, be interesting if such an experiment were performed and gave a conclusive result. The purpose of this paper is to point out respects in which the author is unable to concur in Zemansky's argument and to recall, in connection with sensitized reactions, some already well known facts, derived from a neighboring field, which lead us to believe that sensitized reactions are homogeneous gas-phase reactions. The author rather hesitates to present facts that have been known for a number of years, but since there are some who may not have these facts available and since a full presentation of the facts leads to greater clarity of thought, they will be presented here as briefly as possible.

It has been shown by Stuart [7] that the gases O_2, H_2, CO_2, CO, H_2O, N_2, A, and He can quench the resonance radiation of mercury. The experiment was carried out by illuminating mercury vapor in a resonance bulb with the center of the line 2537 Å. (obtained by using a "resonance lamp") and measuring the intensity of the resonance radiation emitted from the bulb both when it contained no foreign gas and when there was a definite pressure of foreign gas present. It was found that the intensity of the resonance radiation decreased as the pressure of the foreign gas increased and curves connecting the intensity of resonance radiation with the pressure of the added gas were plotted. Further, the gases N_2, A, and He quenched but slightly whereas the other gases, especially H_2,

[6] M. W. Zemansky, *Phys. Rev.*, **31**, 812 (1928).

[7] H. A. Stuart, *Zs. f. Phys.*, **32**, 262 (1925).

O_2, and CO, showed a considerably greater effect. Since the former three gases have no excitation potentials below 4.9 volts it was thought that they transfer excited mercury atoms from the 2^3P_1 state to the *metastabile* 2^3P_0 *state* (4.7 volts) while the rest of the energy goes into relative kinetic energy of the two atoms.[8] This has been actually shown to be the case by the experiments of Wood,[9] Donat [10] and Loria.[11]

Now, there is a theorem by Stern and Volmer [12] which may be applied to the quenching of resonance radiation. It states that if there exists a mixture of excited atoms which may either radiate or lose their energy of activation by collision with molecules of foreign gas (or unexcited atoms of their own sort), then at a pressure of foreign gas at which the intensity of resonance radiation is reduced to half its value when no foreign gas is present, the time between collisions is equal to the mean life, τ, of the activating atom in the excited state. The theorem takes no cognizance of imprisoned radiation nor does it, in the form in which Stuart applied it, consider cases in which excited atoms are being formed by any other mechanism besides absorption of radiation; it further assumes every collision between an excited atom and a foreign gas molecule leads to quenching. Table I gives the half-value pressures as given by Stuart. On applying the Stern-Volmer theorem to these data, it will be seen that if we assign a given radius to the excited mercury atom and make use of the kinetic theory diameter for the other molecules in question, we will have to make use of an efficiency factor, η, which allows for the fact that not all collisions between excited atoms and foreign molecules lead to quenching. One would like to take the quenching efficiency of H_2 equal to 1, since it actually has the lowest half-value pressure and since it is known that it can take up 4.34 volts of energy from excited mercury atoms. Since, however, η is the number of quenching collisions per

[8] O. Oldenberg (*Zs. f. Phys.*, **49**, 609 (1928)) has shown that collisions between argon and excited mercury also lead to a transfer of the mercury atoms to the *normal* state without the emission of radiation.

[9] R. W. Wood, *Phil. Mag.*, **50**, 774 (1925).

[10] K. Donat, *Zs. f. Phys.*, **29**, 345 (1924).

[11] S. Loria, *Phys. Rev.*, **26**, 573 (1925).

[12] O. Stern and Volmer, *Phys. Z.*, **20**, 183 (1919).

collision, it turns out that η would assume a value greater than 1 in the case of O_2. Stuart therefore takes η for O_2 equal to 1, and, on assigning a collision radius for excited mercury (3.4 times the kinetic theory value), calculates the efficiency factors for the other gases. These are tabulated in Table I, for reference.

TABLE I.

(*From Stuart.*)

Gas.	Half-Value Pressure mm.	Time between Collisions at Half-Value Pressure.	Yield ($\eta \times 100$).
H_2.....	0.2	7.10^{-8}	70
O_2.....	0.35	1.10^{-7}	100
CO.....	0.4	8.10^{-8}	80
CO_2.....	2.0	2.10^{-8}	20
H_2O.....	4.0	1.10^{-8}	10
N_2.....	30.	$1.3 \cdot 10^{-9}$	1.3
Ar.....	240.	2.10^{-10}	0.2
He.....	(760.)	3.10^{-11}	0.03
Air.....	1.2	—	—

Recently Stuart's treatment of his data has been criticized by Foote [13] and also by Zemansky.[6] Foote objects to representing the processes occurring in the quenching of resonance radiation as that presented by the Stern-Volmer theorem. He wishes to allow for imprisoned radiation, small amounts of impurities, and the fact that in the cases of N_2, A, and He excited mercury atoms may be formed from metastabile ones by collisions with fast gas molecules. By this latter mechanism he is able to explain away the efficiency factors for N_2, A,[14] and He, but the efficiency factors for the other gases O_2, CO, H_2O, etc. remain unexplained.

An alternative method of treatment is offered by Zemansky. By the use of Milne's theory of imprisoned radiation he is able to show that the number of collisions between mercury atoms in the 2^3P_1 state and foreign gas molecules which lead to quenching of the resonance radiation, is proportional to a fractional power of the pressure of the foreign gas. Thus on plotting the log of the number of quenching collisions

[13] P. D. Foote, *Phys. Rev.*, **30**, 288 (1927).

[14] This explanation is difficult to reconcile with the experiments of Oldenberg on argon, ref. 8, l.c.

against the log of the pressure he finds a straight line with a slope of about 0.5 (actually the slopes vary from 0.4 to 0.6). Since, now, some of these gases have been shown to react after collision with excited mercury atoms he makes the usual assumption that the number of quenching collisions is a measure of the rate of reaction [15] and arrives at the conclusion that the rate of reaction is proportional to a fractional power of the pressure. He takes this fact to mean that the reaction is a heterogeneous one [16] and proposes the following mechanism to account for the rate; (1) Mercury atoms are excited to the 2^3P_1 state by absorption of radiation; they may either (2) radiate, and the radiation eventually get out as resonance radiation, or (3) be transferred to the metastabile state by collisions with foreign gas molecules; (4) these metastabile atoms then diffuse to the front wall of the resonance vessel where (5) the foreign gas molecules actually obtain their energy of activation from them. This mechanism does not admit that foreign gas molecules may be activated by *excited* (2^3P_1) mercury atoms, nor does it allow that *metastabile* mercury atoms may lose their energy of activation to foreign gas molecules before reaching the wall. These two requirements are in contradiction to a number of well known facts as we will now proceed to show.

The most clear-cut of any chemical reaction sensitized by excited mercury atoms is that between hydrogen and copper oxide.[1] Turner [17] has shown, for this reaction, from kinetic theory considerations similar to those of Stern and Volmer, that a straight line can be obtained by plotting the reciprocal of the average reaction rate against the reciprocal of the average hydrogen pressure, and that the average life of a mercury atom in the excited state can be calculated from the ratio of the slope to the intercept of this line, if a suitable radius (2 to 3 times the

[15] This supposes that the first step in the reaction is the rate determining step as is usually the case in reactions of this type.

[16] The fact that a reaction has a rate proportional to the ½ power of the pressure of one of the components does not necessarily mean that the reaction is heterogeneous. See, for example, Bodenstein and Lütkemeyer, *Zs. f. Phys. Chem.*, **114**, 208 (1925), where a chain mechanism is involved to explain the fact that a homogeneous gas phase reaction has a rate dependent on the ½ power of the pressure of one of the components.

[17] L. A. Turner, *Phys. Rev.*, **23**, 464 (1924).

kinetic theory value) be assumed for the excited mercury atom. This mechanism assumes that every collision between an excited mercury atom and a hydrogen molecule results in the activation of the hydrogen, a plausible assumption since the quenching efficiency of hydrogen is known to be high, and that the excited mercury atom reverts to the normal state. The good agreement between the accepted value of τ for the excited mercury atom and the value calculated from this theory could only be obtained if the activation of hydrogen by excited mercury atoms was a homogeneous gas-phase reaction.

Another piece of evidence for the homogeneity of sensitized reactions is to be found in the closely allied field of *sensitized fluorescence*. Franck [18] and his pupils have shown that if a mixture of mercury vapor and metallic atoms of a sort B, having one or more excitation potentials below 4.9 volts, be radiated by light from a cooled quartz mercury arc, the excited mercury atoms thus formed give up their energy of excitation to the B atoms, causing them to emit their characteristic radiation. They further showed that if the B atoms have an excitation potential K (below 4.9 volts) then the difference in energy, $\Delta e = 4.9 - K$, goes into the relative kinetic energy of the two atoms. The atom B, which now radiates, has a translational energy

$$u_B = \frac{\Delta e}{1 + \frac{m_B}{m_{Hg}}}$$

volts and shows a corresponding Doppler broadening. This predicted Doppler shift has actually been observed and its magnitude found to agree quantitatively with that predicted from the theory given above. The reverse process has also been found to occur, namely, if the B atom has a resonance potential a little above 4.9 volts, then if the temperature is high enough, the relative kinetic energy of the two atoms as they come together may furnish enough energy so that a B atom, having an excitation potential of 6.3 volts

[18] For a summary of all the work that has been done in this field, see J. Franck and P. Jordan, "Anregung von Quantensprüngen durch Stösse," p. 216 et seq.

(*Cd*) may be excited, [19] although to a small extent. Such a state of affairs could hardly be expected if the process of sensitized fluorescence were taking place on the wall, as it is very probable that the wall would act as an energy reservoir and take up the excess energy, at any rate the quantitative agreement would not be provided for. Since sensitized reactions should obey the same laws it follows that the activational processes of these reactions take place in the gas phase.

It has also been shown from kinetic theory reasoning [20] that the probability of a collision of the second kind is greatest when the least energy is dissipated into kinetic energy. This has been verified by experiments [21] on the intensity of spectral lines emitted in sensitized fluorescence where it has been found that those lines emitted from a level having energy near 4.9 volts (in the case of mercury sensitization) have a greater intensity than other lines emitted from a level having energy greatly below 4.9 volts. If the process of sensitized fluorescence were taking place on the wall, one would expect as in the above argument that the wall would act as reservoir of energy and that no such correspondence between the intensity of the emitted spectral lines and the energy level from which they came.

The large quenching efficiency of O_2 has been a troublesome point to a number of investigators, for if it is admitted that the probability of a collision of the second kind is greatest when the least energy is dissipated into kinetic energy, it would be expected that H_2 would have the greatest quenching efficiency since it has a dissociation potential at 4.34 volts, it being known that the first electronic resonance potential as well as the dissociation potential of O_2 is well above 4.9 volts. Recently, however, a complete study of the band spectrum of O_2 has been made by Ossenbrüggen [22] who tabulates wave numbers from which the energy of the first seventeen oscillational levels of the (normal electronic) molecule may be obtained. The wave numbers of the band heads in O_2 may be

[19] Cario and Franck, *Zs. f. Phys.*, **17**, 202 (1923).

[20] J. Franck and P. Jordan, "Anregung von Quantumspringen durch Stösse," pp. 211–212.

[21] Beutler and Josephy, *Naturwiss.*, **15**, 540 (1927).

[22] W. Ossenbrüggen, *Zs. f. Phys.*, **49**, 167 (1928).

represented by the equation

$$\nu_0(n'n) = 49{,}777.3 + [721.2(n' + \tfrac{1}{2}) - 13.3(n' + \tfrac{1}{2})^2] - [1576.74(n + \tfrac{1}{2}) - 11.37(n + \tfrac{1}{2})^2], \quad (1)$$

where n' is the oscillational quantum number of the molecule in the excited and n that of the normal electronic state. The vibrational frequency of the molecule in the normal electronic state is given by

$$\omega^n = \frac{\partial \nu_0}{\partial n} = (-)[1576.74 - 22.37(n + \tfrac{1}{2})]. \quad (2)$$

On plotting ω^n against n the first seventeen points lie on a straight line. Assuming, as do Birge and Sponer [23] that a linear extrapolation of these data may be made, we find that the line cuts the n axis at $n = 69.5$ and the heat of dissociation of O_2, calculated in the usual manner, is found to be about 6.6 volts. Therefore, O_2 must have oscillational levels corresponding to all the quantum numbers from $n = \frac{1}{2}$ to $n = 69.5$. By integration of $\int_{\frac{1}{2}}^{m+\frac{1}{2}} \omega^n dn$ from equation (2) the energy of the oscillational level which lies nearest to 4.9 volts, the excitation potential of the excited mercury atom, may be calculated and it is found that the energy of the oscillational level corresponding to $n = 33.5$ is 4.86 volts. If O_2 can take up this amount of oscillational energy by collision of the second kind with excited mercury atoms [24] then it is easy to account for the high quenching efficiency of O_2 since very little energy (0.04 volts) is dissipated into kinetic energy.

CONCLUSION.

1. Zemansky's treatment of the quenching of resonance radiation has been reviewed with conclusions unfavorable to the theory there proposed.

[23] R. T. Birge and H. Sponer, *Phys. Rev.*, **28**, 259 (1926). Birge and Sponer had data at hand for the O_2 bands from which they could derive the oscillational levels for quantum numbers 11 to 17 and were able to calculate the heat of dissociation.

[24] Oldenberg (l.c.) has shown that CO and N_2 may take up oscillational energy from 2^3P_1 mercury atoms, transferring them to the metastabile 2^3P_0, state, thus accounting for the fact that CO and N_2 have higher quenching efficiencies than A and He.

2. The activational processes of sensitized reactions have been discussed and it has been pointed out that these processes most probably occur in the gas phase.

3. The high quenching efficiency of O_2 for mercury resonance radiation has been accounted for by assuming that O_2 can take up energy of oscillation by collision of the second kind with excited mercury atoms.

The Chemical Warfare School of Applied Chemistry at The Massachusetts Institute of Technology is described by CAPT. M. E. BARKER (*Chemical Warfare*, 1928, *14*, 372–373). This school is a graduate course covering two full calendar years. The preparatory subjects or professional prerequisites usually include calculus, chemical principles, and industrial stoichiometry. The required subjects include chemical engineering, differential equations, industrial organization, industrial chemistry, organic chemistry laboratory, advanced inorganic chemistry, powders and explosives, chemical engineering practice, and a research and thesis topic. The chemical engineering practice includes three periods of eight weeks each, spent, respectively, in heavy chemical manufacturing plants in Boston, the paper, pulp, and cellulose factories at Bangor, Maine, and the steel mills and by-product coke ovens at Buffalo, New York. The 8 or 10 electives, which must also be completed, are usually related to the subject of the thesis, and are selected from groups in organic chemistry, chemical engineering, and mechanical engineering.

J. S. H.

Spontaneous Ignition of Stable Manure. L. H. JAMES, G. L. BIDWELL, and R. S. MCKINNEY (*Jour. Agric. Research*, 1928, *36*, 481–485) report the repeated spontaneous ignition of a pile of heating stable manure. The pile was 200 feet long, 50 feet wide, and ranged from 1 foot to 20 feet in height. The center of the pile had a temperature of 51° to 66° C. The outer layers had a considerably higher temperature. As a rule, the highest temperature was within 6 inches of the surface where the the manure was tightly packed, and within 1.5 or 2 feet of the surface where the manure was loosely packed. At the surface, the smoking straw had a temperature of 76° C., the glowing straw a temperature of 132° C.

Introduction of oxygen into a section of the manure produced an increase of 26.5° C. in its temperature in 30 minutes. The temperature measurements were made by means of a potentiometer and a thermocouple which was introduced into the manure.

J. S. H.

THE EFFECT OF DARK SURROUNDINGS UPON VISION.

BY

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IT has long been known that the sense of vision is at a disadvantage when trying to discern dimly lit objects in the midst of a brightly lit field. The attempt to see the interior of a building, by natural light from the outside, by looking in at an open window will exemplify such a situation; or the attempt, at night, to see outside objects from a well-lighted interior. The essential setting consists of a comparatively dark field, of limited size, surrounded by an extensive brightly-lighted area. Under the circumstances, casual observation soon convinces one that the objects within the dark area are more easily seen with the bright surroundings removed or darkened.

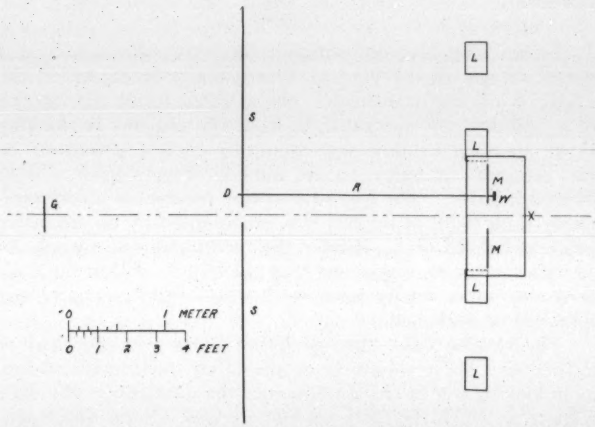
The reverse case, that of vision upon a bright field of limited size, set in relatively or absolutely dark surroundings, as in looking out of the window into the daylight, is one with respect to which the facts are less obvious. Some years ago, however, one of the authors [1] was able to show that in this situation also a certain temporary impairment of visibility is at hand, although of relatively small degree, and that the best condition for vision is one in which the brightness of the surroundings is about equal to that of the limited field upon which the eyes are called upon to work.

The conditions represented by the bright field set in darkness are of twofold importance. In experimental work in vision, it has often been the procedure to present the field to the eye by having the subject look into an eye-piece. Ordinarily, the field so seen will be surrounded by darkness; and the applicability of results so obtained to the usual

[1] Cobb, Percy W., "The Effect on Foveal Vision of Bright Surroundings." *Jour. Exp. Psychol.*, I, 1916, pp. 540–566.

conditions of vision on widespread bright fields is open to some doubt. A second situation of this description is that in which a person sits near a table-lamp, reading a highly illuminated page in a room which is otherwise dark, and in which therefore the paper presents a high-light. While economical of light, it is a question whether this situation facilitates vision to the best advantage.

FIG. 1.



General Plan of Apparatus. The subject sat at the table with his eyes at *X*, viewing a central portion of the screen *S–S* limited by the opening in the mask *M–M*. By means of the hand-wheel *W* and the rod *R* he was able to move the lower stylus to keep it in opposition to the upper one.

A question of critical interest in this connection is the angular distance to which the borders of the dark surroundings must be removed from the center of the visual field in order to abolish the adverse effect upon vision. In the experimental work cited, the bright working field was small and of rectangular shape, and its dimensions in the visual field, vertically and horizontally, were 2° and 2.6°, respectively. The work about to be described is an attempt to determine how far the borders of the dark surroundings would have to be removed from the line of direct vision (or how far the bright working-field would have to be extended) in order that visibility at the center should be at its best.

To provide such conditions, a large vertical white screen was erected near one end of a large room. This screen (*S–S*, Fig. 1) extended upward 2.44 meters (8 feet) from the floor, and was 4.26 m. (14 feet) wide. The subject sat at a table near the other end of the room, with his eyes (at *X*, Fig. 1) directly opposite the center of this screen and at 3 m. (9 feet, 10 inches) distance, and with his head supported by a forehead-and-chin rest (Fig. 4). The screen was uniformly illuminated to a brightness of 10 millilamberts by eight gas-filled tungsten-filament lamps. This required an illumination of approximately 11.6 foot-candles. The lamps were enclosed in boxes, four of which, *LLLL*, are shown in Fig. 1.

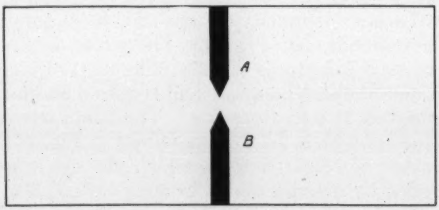
The extent of bright field to which the eye was subject was controlled by a series of diaphragms (*M–M*, Fig. 1) with various central openings, any one of which could be slid into a frame, and held in a vertical position opposite the subject and at a distance of 45 cm. (18 in.) from his eyes. The end of the room in which the subject sat was kept almost completely dark by curtains of black material, hung in the plane of the diaphragm *M–M* and completely filling the cross-section of the room, and in consequence the side of the diaphragm toward the subject reflected almost no light toward his eyes. In addition, the diaphragms and the frame supporting them were painted a dead black. The opening in the diaphragm thus presented a border of variable dimensions, within which a limited central portion of the illuminated white screen *S–S* could be seen in the midst of complete darkness.

The test-object was located at the center of this white screen, and consequently appeared within the area exposed by the diaphragm. Owing to the difference in the distances (45 cm. and 3 meters) it could not be made to appear centrally with both eyes at once. With the eyes fixed upon the test-object, there was sometimes an apparent doubling of the diaphragm-opening, which was especially noticeable with the smaller sizes, and a possible source of disturbance which will be discussed later.

The test-object (Fig. 2) consisted of an irregularly moving stylus, *A*, and the subject was required to keep a second stylus, *B*, in exact opposition to it by means of a hand-wheel

(*W*, Fig. 1) conveniently located on the table at his right hand. These appeared in a rectangular opening 152 mm. (6 in.) wide, and 70 mm. (2¾ in.) high, which was made in a sheet of thin metal forming the central part of the white

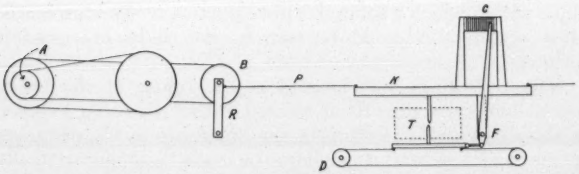
FIG. 2.



The Test-Field. The upper stylus *A* moved slowly and irregularly back and forth. The subject's task was to keep the lower stylus *B* in a position opposite to it.

screen. The moving (master) stylus was seen in silhouette, projecting downward from the upper border, and the following stylus projected upward from the lower border, both working close behind the margins of the opening. They were each 6.4 mm. (¼ in.) wide, tapered to a sharp point for an equal length, and the points cleared each other by 4.8 mm. (3/16 in.) in passing. Both of these were lacquered dead black.

FIG. 3.



Detail of the Mechanism. The four eccentric pulleys at the left, when *A* was driven, gave the rocker *R* an irregular oscillatory motion, transmitted to the carriage *K*, bearing the upper stylus. The pulley *D* is fixed on the end of the rod *R*, Fig. 1, and actuates the lower stylus. The particular bar of the commutator *C*, upon which the contact rested, indicated the discrepancy between the two styluses, and by this means the appropriate counter was worked at intervals of 0.64 sec. whenever the master-contact was made.

The moving stylus was mounted on a sliding carriage (*K*, Fig. 3), and driven by a mechanism consisting of a piano-wire running over a set of four pulleys of different diameters, each one bored 3 mm. (⅛ in.) eccentrically.

One of these (*A*, Fig. 3) was fixed on its shaft and was driven slowly, the wire caused the others to rotate, and the eccentricity of the pulleys gave rise to the movement of one of their number *B*, which was mounted on a rocking arm, from which its movement was communicated, by another

FIG. 4.

A Subject in Working Position. The head-rest, the mask *M–M* and the hand-wheel *W* are shown. Compare with Fig. 1.

wire *P*, to the sliding carriage *K* and to the master-stylus. This wire was kept taut by means of a counter-weight, acting through a wire attached to the opposite end of the carriage *K*. The two other pulleys revolved freely on fixed axes. The effective diameters of the four, measured at the bottom of their respective grooves, were proportioned to each other approximately as 5, 7, 9 and 11. These numbers therefore represented the relative periods of four approximately harmonic movements each of 6.4 mm. (¼ in.) length between extremes, and the movement of the axis of pulley *B*

was the composite of these three. The possible extremes of movement of the center of the pulley *B*, which were seldom reached, were therefore 25 mm. (1 in.) apart. The diameters of the pulleys are represented by numbers which are prime to each other; wherefore even if the diameters were accurately proportioned, the identical movement could not be repeated

Fig. 5.

General View of Apparatus. Compare with Figs. 1 and 3. The reverse side of the screen *S–S* shows at the right. The battery of solenoids and the counters thereby operated are shown in the foreground.

for a very long time. Thus the drive pulley actually made one revolution in 25 seconds. Hence the other three completed one revolution in 35, 45 and 55 seconds respectively, and the time for the complete cycle, granting these proportions to be accurate, was the least common multiple of these four, 17,325 seconds or 4 hours, 48 minutes and 45 seconds. Need-

less to say, it was not possible to anticipate the movement, although this was never what could properly be called rapid.

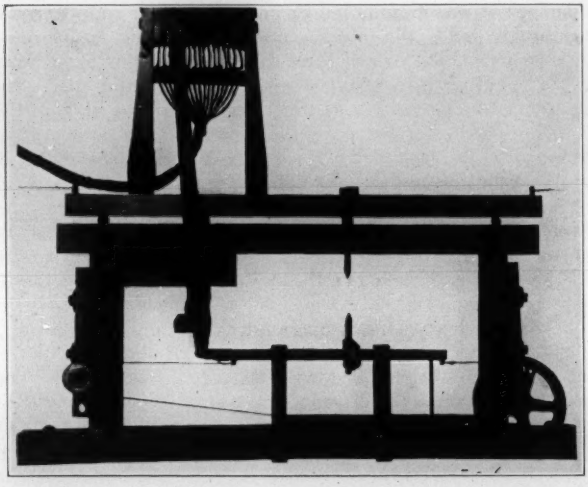
On the further wall of the room, 2.06 meters (6 ft. 9 in.) beyond the opening in the screen, a sheet of white cardboard (*G*, Fig. 1) was placed, ruled with india ink in lines about 0.53 mm. (.021 in.) wide, 4.8 mm. (3/16 in.) apart and inclined at 45°. This was so placed as apparently to fill the screen opening; it was illuminated by an independent lamp to equal brightness with the screen, and formed the background against which the two styluses were seen. It appeared from a few preliminaries that this sort of a ground made the apparatus more sensitive, but this has since appeared doubtful.

The degree of accuracy with which the subject was able to follow the moving stylus was measured by an automatic recording apparatus. The sliding carriage bore a set of 17 insulated copper bars which formed a commutator, over which a small rolling contact could pass (*C*, Fig. 3), attached to the upper end of a light lever. The fulcrum of the lever, *F*, is attached to the sliding carriage, and its lower, short arm is attached to a small slider which carries the following stylus. This is operated by the pulley *D*, Fig. 3, by means of the hand-wheel *W* and rod *R* shown in Fig. 1. The result is, that if the lower stylus follows the upper one *exactly*, the contact will remain stationary at the center of the commutator. Otherwise, the bar on which the contact rests is an index of the discrepancy. Each bar of the commutator was electrically connected to a solenoid operating a counter, and the discrepancy was recorded, every 0.64 second, by a master contact which permitted that one of the 17 counters to operate which was connected with the bar of the commutator upon which the rolling contact rested at that instant. Fig. 5 is a general view of the recording apparatus, showing the battery of solenoids with attached counters and the mechanism carrying the styluses, which is again shown in detail in Fig. 6.

The counter-readings, in connection with the displacement corresponding to each bar, therefore constituted a set of classified data, showing at once the distribution of the subject's inaccuracy in following the master-stylus. Such a distribution, taken over the experimental period of 5 minutes,

yielded two results,—the first, a mean displacement, showing the systematic tendency on the part of the subject to set the follower somewhat off its geometrically "opposite" position; the second, the index of scatter about that point of mean displacement. For the second of these, the standard deviation was used; that is, the square root of the mean squared deviation of the following stylus, measured from its mean position relative to the master-stylus.

FIG. 6.



The traveling carriage, following stylus and commutator shown in Figs. 3 and 5.

The extent of the bright fields exposed by the various diaphragms could be expressed in various ways. The distance from the eyes of the subject to the diaphragm was uniformly 45.3 cm. (17.8 in.). In the following table are given the height and width of each diaphragm opening, the rectangular area of the same (in square feet) projected at a distance of 10 ft. upon a plane normal to the line of vision, as upon the screen *S*, and the angle subtended by the radius of a concentric

circle in the same plane equal in area to the rectangle. This last is, therefore, an approximate index of the angular distance to which the border of the dark surroundings has been removed from the line of direct vision in each case.

	Number.					
	1	2	3	4	5	6
Dimensions, mm.	25 x 78	52 x 105	101 x 154	203 x 254	405 x 460	400 x 710
Proj. area, sq. ft...	.95	2.7	7.6	25.0	91.	138.
Angle.....	3.2°	5.3°	8.9°	15.7°	28.2°	33.6°

The standard deviations are given in Table I, separately for each of the thirteen subjects. Each one is obtained from the pooled and classified data of 12 runs of five minutes each under the conditions indicated. The actual number of data recorded on the counters per five minutes was somewhat variable and in the main more than 400, each result stated in the body of the table representing the standard deviation computed from a mass of classified data ordinarily in excess of 5000 in number, and seldom less. Reference to the last column of the table will show that the uncertainty represented by the standard deviation was unequal for the different subjects, ranging from 0.475 minutes' visual angle to 1.067, a ratio of a little more than 2 : 1. The geometric mean for all subjects was 0.725 minutes. These figures are therefore of about the same order as the values stated for visual acuity, one minute or somewhat less. In the separate columns of the table, the mean values of the standard deviations are given for the various areas of bright field, arbitrarily numbered from 1 to 6. The second column under each of these is the percentage deviation of the separate mean from the mean for all six of the mask-openings, last column; and at the foot of the table are given (*a*) the averages of these percentage deviations from the mean of all, with due respect to sign, at each stage. The conclusion would be that a rather abrupt change takes place between stages 3 and 4 as the extent of the bright field is increased, in the sense of greater precision of following to the extent of 6 or 7 per cent. As subject No. 12 was somewhat erratic in stages 1 to 3, the second

TABLE I.

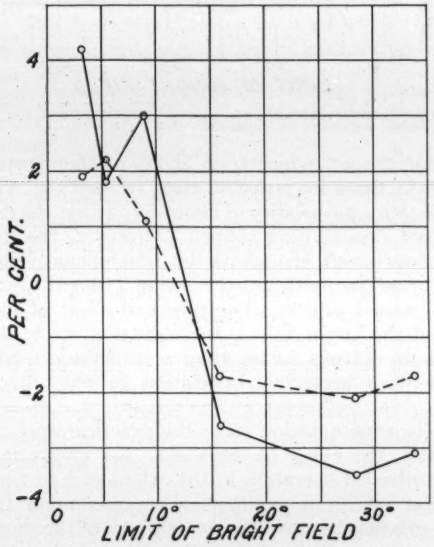
The Standard Deviation of Settings in Minutes' Visual Angle for the Six Conditions of the Experiment and for Each of the Thirteen Subjects Participating.

At the head of the table are given the various extents of the bright field, in the upper row in square feet at 10 feet distance, and in the lower in degrees angle subtended by the radius of an equal circle. The number following each decimal in the body of the table is its percentage deviation from the mean of the six for the same subject. At the foot: *a*, mean percentage deviation for all subjects, *b*, for all except No. 12. At the extreme lower right is given the geometric average of the thirteen averages in the column above.

Subject.	Extent of Bright Field.												Av.
	.95		2.7		7.6		25		91		138		
	3.2°		5.3°		8.9°		15.7°		28.2°		33.6°		
1.....	.983	− 1	1.032	+4	1.063	+ 7	.973	− 2	.970	− 2	.938	− 6	.993
2.....	.617	+ 6	.632	+8	.548	− 6	.524	−10	.614	+ 5	.570	− 2	.584
3.....	1.096	+ 3	1.098	+3	1.078	+ 1	1.020	− 4	1.046	− 2	1.062	0	1.067
4.....	.930	0	.988	+6	.914	− 2	.895	− 4	.890	− 4	.967	+ 4	.931
5.....	.891	+ 3	.874	+2	.893	+ 4	.830	− 4	.841	− 2	.837	− 3	.861
6.....	.472	− 1	.466	−2	.490	+ 3	.494	+ 4	.464	− 2	.463	− 3	.475
7.....	.527	+ 3	.518	+2	.515	+ 1	.499	− 2	.496	− 3	.506	− 1	.510
8.....	.928	+ 7	.887	+2	.850	− 2	.876	+ 1	.805	− 7	.852	− 2	.866
9.....	.642	− 7	.700	+1	.709	+ 3	.703	+ 2	.688	0	.696	+ 1	.690
10.....	.724	+11	.658	0	.622	− 5	.630	− 4	.638	− 3	.658	0	.655
11.....	.653	0	.640	−2	.660	+ 2	.674	+ 4	.618	− 5	.652	0	.650
12.....	.868	+32	.627	−4	.828	+26	.563	−14	.528	−20	.525	−20	.656
13.....	.747	− 1	.782	+3	.806	+ 7	.750	− 1	.753	0	.697	− 8	.756
a.....		+4.2		+1.8		+3.0		−2.6		−3.5		−3.1	.725
b.....		+1.9		+2.2		+1.1		−1.7		−2.1		−1.7	

line, *b*, at the foot of the table gives the mean values for the other twelve subjects, excluding his. The results still lead to a similar conclusion, except that the change is of less extent, amounting to about 4 per cent. These results are plotted in Fig. 7, from which it will be noted that the exclusion of subject No. 12 yields a smoother curve.

FIG. 7.

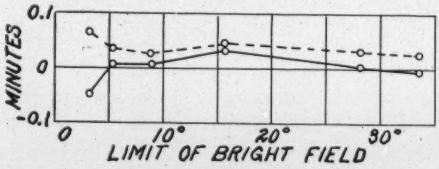


Percentage variations in the uncertainty of following, referred to the mean of all values as 0. Solid line, all 13 subjects; broken line, subject No. 12 omitted.

A word is still to be said about the systematic deviation (or deviation of the average setting), of the various subjects from the point of geometric opposition, as contrasted with the "scatter" represented by the standard deviation which has just been discussed. This also is various for the different subjects; averaging as much as 0.47 minute to the left in one extreme case, and 0.20 minute to the right in the opposite extreme. Comparison of the results for the variously sized

fields (see Fig. 8, solid line) would indicate a tendency for the individual to set slightly to the left of his average position when the smallest opening is used, to the extent, in the

FIG. 8.



Deviation of mean position, with reference to geometric opposition, in minutes' visual angle. Solid line, all subjects; broken line, No. 12 omitted.

average for the 13 subjects, of about 0.046 minute, which value is 3.54 times its probable error (± 0.013). This ratio would indicate a probability of about 60 : 1 that the difference 0.046 is not due to pure chance. However, the difference seems almost small enough to be insignificant, since it is less than one-twentieth of the value ordinarily stated as "normal" visual acuity. The principal effect of increasing the area of the bright field is the reduction in the degree of scatter of the setting, rather than a systematic tendency to set away from geometric opposition in one direction or the other.

There is some question as to the practical application of this result. The effect of decreasing the uncertainty of a visually controlled operation to the extent of 4 to 7 per cent. will depend much, in any particular case, upon the ratio primarily existing between the uncertainty of the sense-organ on the one hand, and on the other, the fixed requirement imposed upon it by the character of the work. In Case I, let us say, this ratio is such that the failures to see outnumber the successes by a large majority. In this case, decreasing the uncertainty of vision will be equivalent to increasing the "tolerance" in the requirement in just about the same ratio. The successes, for instance, initially 10 per cent., will be increased about to 10.7 per cent. by a 7 per cent. enhancement of the certainty of the eye brought about, let us say, by improvement in the lighting. In Case II, however, in which

the successes are initially only slightly below 100 per cent., say 98, no such rule will apply. The probability tables indicate that in this instance the same shrinkage in the uncertainty of vision will increase the successes no more than to 98.72 per cent.—an increase of 0.7 instead of 7 per cent. However, if we are interested in the decrease in the failures, we find that these have shrunk from 2 to 1.3 per cent.; that is, they have decreased by 35 per cent. of their initial number. The fact should never be overlooked that in the industries the economic significance of such an improvement will depend entirely upon the values that are to be attached to successes and failures respectively, which, in turn, depend upon many things not included within the psycho-physiology of the worker.

There is a further unfavorable factor undoubtedly present in the practical situation which does not appear in its present experimental counterpart. That is the effect of the glance of the worker into the dark surroundings of his working field from time to time, either as he relaxes for an instant from his work, or as he necessarily peers into the darkness for some definite purpose. In the latter case, as we know, there is an enforced delay, while his eyes adapt themselves to the dim conditions,[2] and in either case, upon their return to the work, an effect is, in all probability, present such as that shown by the experiment, but temporarily, at least, to a heightened degree. With respect to this consideration then, the experimental differences do not reflect all of the effect practically present.

In considering possible applications of the results here given, it is important to remember that in the experiment the edges of the diaphragm limiting the extent of the bright field are within arm's length, while the test-object is at several times this distance from the subject's eyes. It has already been remarked that this made it impossible for both eyes at once to see the test-object central within this area, and that, as a matter of fact, the smaller openings were seen double when the eyes were fixed upon the test-object. This situation is not of the sort encountered in practical situations.

[2] Cobb and Moss, "Lighting and Contrast," *Trans. I. E. S.*, XXII, 1927, pp. 198–202.

A well-illuminated sheet of print, for example, presents a condition in which the borders of the bright area are in the plane for which the eyes are accommodated and converged. It is perhaps to be expected that this latter situation, being of the kind to which the eyes are accustomed by life-long usage, would be less disturbing than the laboratory situation of the present experimental work. It should follow from this, that in the practical situation the differences would be smaller than the experiments have shown, or that the eyes would without greater disturbance tolerate a closer approach of the dark surroundings to the line of direct vision than these results would indicate.

SUMMARY.

1. The purpose of the present paper is to estimate the extent of bright surroundings necessary to abolish the known, adverse effect of dark surroundings upon vision on a small, bright, working field.

2. The test of vision used was the accuracy with which the subject could keep a manually operated stylus in opposition with another, slowly and irregularly moving, mechanically operated stylus. Both of these were seen in silhouette upon a small, bright field.

3. The results here stated are derived from a total of 390,000 measurements.

4. The precision with which the subjects could follow the moving stylus in general was highest with the largest extent of bright surroundings, lowest with the smallest. Although represented by some 65,000 measurements for each of the six sizes of surrounding field used, the results were still somewhat irregular.

5. The extreme difference in precision was from 4.3 to 7.7 per cent. A large part of this difference, 2.8 to 5.6 per cent., occurred when the border of the bright surroundings was pushed outward from 8° to as far as 16° from the visual line. The plotted results would indicate that there is no advantage to be gained by extending the bright surroundings beyond this.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THIRTEENTH ANNUAL MEETING OF THE OPTICAL SOCIETY OF AMERICA.

THE thirteenth annual meeting of the Optical Society of America was held at the Bureau of Standards on November 1 to 3, inclusive. The meeting was opened by the Secretary of Commerce, who delivered a short address of welcome.

An extensive exhibit of optical instruments, appliances, books, and photographs was arranged by the bureau in connection with the meeting. The latest commercial instruments produced here and abroad were shown by representative manufacturers, while instruments in regular use were on view in the laboratories. A special feature of the exhibit was a series of microscopes illustrating the development of this important instrument from 1665 to the present day. This collection was loaned by the Medical Museum of the United States Army. A collection of photographs and books, illustrating the development of optics, was made available through the courtesy of the Smithsonian Division of the Library of Congress.

This meeting of the Optical Society was designated by the executive council as "The Michelson Meeting" in honor of Prof. Albert A. Michelson, whose first communication on a method for measuring the velocity of light was published just fifty years ago. Professor Michelson on November 2 announced the results of his repetition of the Michelson-Morley experiment on ether drift, his latest work confirming the famous experiment of 1887 in showing the absence of any measurable variation in the velocity of light in different directions.

One of the most interesting features of the meeting was the showing of the remarkable motion picture film depicting the rotation of the planet Jupiter. This film was made by Prof. W. H. Wright at the Lick Observatory in coöperation with the Eastman Research Laboratories.

On the evening of November 2 a dinner was held in honor of Professor Michelson. At this dinner Dr. Herbert E. Ives

* Communicated by the Director.

presented to the society the Frederic Ives medal, which Doctor Ives has endowed in honor of his father, and which is to be awarded by the Optical Society of America each year for distinguished work in optics.

Papers by members of the bureau's staff were as follows:

A telescope objective especially free from spherical aberration, by I. C. Gardner;

An optical depth gauge, by I. C. Gardner;

An interference method for the determination of central and oblique aberrations, by A. H. Bennett;

Apparatus for the measurement of the reflective and transmissive properties of diffusing media, by H. J. McNicholas;

Apparatus for accurate and rapid measurement of spectral transmission and reflection, by K. S. Gibson;

The history and present status of the physicist's idea of light, by Paul R. Heyl;

The wave-lengths of the *D* lines of sodium in absorption and emission, by C. C. Kiess;

Recombination of atomic ions and electrons, by F. L. Mohler and C. Boeckner;

Light scattering in liquids, by R. M. Langer;

The absorptive properties of carotin and xanthophyll in the visible and ultraviolet, by H. J. McNicholas;

Least retinal illumination by spectral light required to evoke the "blue arcs of the retina," by Deane B. Judd.

NEON VISIBILITY TESTS.

DURING August and September, a visibility test on the light from a neon lamp as compared with the light from an incandescent filament lamp with red color filter was conducted at Moody Point, Maine. The apparatus for the test was erected at a place on the coast, where a range for observation of about 4.5 miles was available, the particular location having been selected on the basis of fog records of the Bureau of Lighthouses for some years. The apparatus was in no sense an aviation beacon, but was designated solely for observation by observers patroling the shore.

The rotating experimental beacon was so operated that 3 flashes of light could be seen successively—a neon flash, a red

flash from an incandescent lamp with color screen to match the neon color, and a clear flash from an incandescent lamp without color screen. The apparatus used to produce the flashes consisted of three lens units, each with its corresponding light source (lamp). These lens units were plano-convex lenses, of 140 millimeters focal length, 110 millimeters aperture, the actual light source in each case being a hole 15 mm. in diameter in a metal plate fixed in the focal plane of the lens, each illuminated by its individual lamp.

For the neon lamp and the incandescent lamp with red color filter, the 15 mm. aperture in each unit had the same candlepower, the same color, and the same horizontal light distribution as closely as was experimentally possible. When the red color filter was removed from its unit the two incandescent beams were also of approximately the same candlepower, color, and horizontal distribution. Three different neon lamps of the hot cathode type were used. The complete equipment, with motor, rheostats, and electrical measuring instruments, was erected in a small shed.

Thirty-three sets of observations were made; in clear weather, in haze, in fog, and in rain. One fog observation was made in daytime. The method of observation varied somewhat, depending on the weather, but generally observations were made from 5 stations, approximately 4.5, 3.5, 3, 2.5 and 1.25 miles from the beacon. The observer walked away from the beacon to the end of the range and back, or from the end of the range towards the beacon. Two persons were engaged on the work,—one observed while the other attended the apparatus, and alternately.

Observations were made with the naked eye and with a photometric wedge. No differences, sufficiently great to be detected by the methods used in this test, were found between the visibility of light from a neon lamp and light of the same color, candlepower, and horizontal distribution produced by an incandescent filament lamp with color screen.

With regard to the comparison of the clear incandescent lamp and incandescent lamp with red color screen, the red filter does not increase the range under any weather conditions, but there is some evidence that the red filter does not reduce the range as much in foggy weather as it does in clear weather.

A SYSTEM FOR FREQUENCY MEASUREMENT BASED ON A SINGLE FREQUENCY.

AN accurate method of rapidly checking the frequencies of piezo oscillators used as the frequency standards for stations has been developed at the bureau and is in daily use. The method is suitable for calibration of either piezo oscillators or frequency meters in terms of a standard temperature-controlled piezo oscillator. The accuracy obtained is dependent only upon the accuracy of the standard piezo oscillator.

The apparatus required consists of a temperature-controlled piezo oscillator the frequency of which is a multiple of 10 kc., a 10 kc. radio-frequency generator, an auxiliary generator covering the range of frequencies desired, a special beat indicator, an audio-frequency generator, and a frequency meter.

The radio-frequency generator is adjusted and maintained at 10 kc. in terms of the standard piezo oscillator. The correct adjustment is shown by a special form of beat indicator which gives both visible and audible indication when the radio-frequency generator is so adjusted that a harmonic of its frequency is exactly the same as the frequency of the standard piezo oscillator. A second auxiliary radio-frequency generator is then set approximately by means of a frequency meter to the assigned frequency of the broadcasting station whose piezo oscillator is to be tested and then adjusted to the exact frequency, which is a harmonic of the ten-kilocycle generator, by the special beat indicator.

After these adjustments are made an audible note will in general be heard when listening in the telephone receivers of the piezo oscillator under test. This note represents the difference in frequency between the piezo oscillator and that of the auxiliary generator. The beat note heard in the telephone receivers of the piezo oscillator is then matched with a similar note from a calibrated audio-frequency generator. This audio-frequency value is then added to or subtracted from the frequency as given by the harmonic of the 10 kc. generator.

The method has the advantages of great accuracy, high precision, adaptability to almost any frequency measurement, and ease of operation.

A paper which has been prepared describing this method will be published shortly.

RADIO-FREQUENCY TRANSFORMER THEORY.

RADIO-FREQUENCY transformer theory has for some time been reduced to mathematical treatment. The accepted equations are simple and usually quite effective but in many cases, computations based on these equations are not in entire agreement with careful laboratory measurements. This lack of agreement was considered in a paper, "Note on Radio-frequency Transformer Theory," by Harry Diamond and E. Z. Stowell, Proceedings, Institute of Radio Engineers, September, 1928. It was found to be due chiefly to the existence of a capacitance coupling between the primary and secondary windings which modifies the transformer performance, but the effect of which is usually considered negligible. When this factor is not neglected, the resultant equations which are developed in this paper yield a closer agreement with experimental data. Copies of this paper are not available from the Government.

THERMAL EXPANSION OF MULLITE FROM 20 TO 1800° C.

A BRIEF description of an apparatus for making thermal expansion observations of refractories from 20 to 1800° C. appeared in Technical News Bulletin No. 134 (June, 1928).

A study of the expansion behavior of mullite, prepared from raw materials obtained from various sources, was recently completed with this apparatus. These materials are as follows:

Sample *A* prepared from andalusite.
Sample *B* prepared from dumortierite.
Sample *C* prepared from Indian cyanite.
Sample *D* prepared by electrically fusing the necessary proportions of alumina and silica to produce mullite.

Specimens measuring approximately 1 by 1 by 6 inches were used for expansivity measurements. A comparison of the expansion characteristics of the several specimens of mullite is given in the following table.

Sample.	Average Coefficient of Linear Thermal Expansion from 20 to 1000° C.		Total Expansion at 1000° C. in Percentage of Unit Length.		Contraction Commences at		Average Coefficient of Linear Thermal Expansion from 20 to 1400° C.		Temperature at Which Maximum Expansion is Reached.		Maximum Total Expansion in Percentage of Unit Length.	
	First Run.	Second Run.	First Run.	Second Run.	First Run.	Second Run.	First Run.	Second Run.	First Run.	Second Run.	First Run.	Second Run.
	$\times 10^{-6}$	$\times 10^{-6}$			°C.	°C.	$\times 10^{-6}$	$\times 10^{-6}$	°C.	°C.		
A....	5.8	5.2	0.51	0.46	None	1770	6.5	5.7	1795	1770	1.390	0.995
B....	5.6	5.6	.495	.495	1400	1520	5.0	5.2	1400	1520	.685	.745
C....	5.4	5.6	.476	.490	1370	1700	[1]4.9	5.5	1370	1700	.603	.842
D....	5.0	5.3	.494	.520	1425	1600	5.4	5.3	1430	1600	.767	.840

[1] Coefficient refers to temperature range, 20 to 1260° C.

All specimens had been fired to at least 1400° C. previous to testing. The maximum temperature reached in the furnace while testing the various materials was as follows:

Maximum Temperatures in Degrees C.

	First Run.	Second Run.
A	1795	1800
B	1670	1730
C	1795	1800
D	1765	1765

Sample "*A*" did not contract, during the initial heating, up to the maximum temperature (1795° C.) used. As shown in the table, it was the only specimen that did not contract during heating. The rate of expansion increases decidedly at about 1500° C. Petrographic examination indicates this material to be composed largely of well developed crystals of mullite and some corundum.

Sample "*B*" has a nearly uniform rate of expansion from 20 to 1500° C. with the exception of an interval between 600 to 700° C. where the rate increases appreciably. Petrographic examination of sample "*B*" indicated a large percentage of glass intermingled with mullite. It contains no corundum.

In spite of sample "*C*" having been heated at 1400° C. for ten hours, shrinkage during the first run commenced at 1250° C. Petrographic examination shows that the second heating caused a considerable growth in the size of the crystals.

Petrographic examination of sample "*D*," after the first heating, shows the material to be composed almost entirely of mullite. Only a small percentage of corundum and glass is present, which is in contrast to samples "*A*" and "*C*."

The rate of thermal expansion of these various specimens of mullite is approximately the same from room temperature to 1000° C. Considerable differences occur in their expansion behavior at the higher temperatures.

Cod Liver Oil. CHARLES E. BILLS (*Chem. Rev.*, 1927, *3*, 425–442) has made an elaborate review of the chemical literature on cod liver oil, citing 90 papers in his bibliography. This oil was originally obtained by natural disintegration or "rotting" of the livers. This process was displaced, first by the steam kettle, then by direct steam rendering. The "stearine" is removed from the crude product by chilling and filtration. The occurrence of 17 fatty acids in cod liver oil has been reported; the presence of 9 of these acids is reasonably well established, the presence of the remaining 8 acids less well established. All the known acids fall into a broad series $C_nH_{2n-2x}O_2$ where n has a value between 14 and 22 and x is the number of double bonds which may range from 0 to 6. Morrhuic acid or sodium morrhuate, which has been used in the chemotherapy of tuberculosis and leprosy, is really a cod liver oil soap prepared for intravenous administration. The oxidation and consequent rancidity of cod liver oil is an autocatalytic process accelerated by the formation of organic peroxides and retarded by foreign substrates; they are most readily avoided by expeditious rendering. Cod liver oil may be hydrogenated; this process destroys both the vitamins and the fishy smell. Inorganic constituents may be present in the oil, such as iodine (0.0001 to 0.0005 per cent.), bromine, chlorine, nitrogen, phosphorus, organic sulphur, zinc, and the alkalies. The unsaponifiable fraction contains cholesterol, other complex alcohols, a hydrocarbon (squalene or spinacene), a lipochrome or pigment, and vitamins (fat-soluble A and fat-soluble D).

J. S. H.

Mode of Action of Vitamin D. The fat-soluble D vitamin or antirachitic vitamin is an important factor in the prevention of rickets. LESLIE J. HARRIS of Cambridge University (*Science Progress*, 1928, *23*, 68–74) discusses the theory that this vitamin governs the acidity (hydrogen ion concentration) of the intestinal contents, and thus controls calcium metabolism. The vitamin causes an increased acidity in the intestine. As a result, ingested calcium phosphate becomes more soluble, is absorbed in greater amount into the blood stream, and is deposited in greater amount in the bones. Lack of the vitamin and resulting decreased acidity (increased alkalinity) of the intestinal contents converts the calcium salts into insoluble compounds, and prevents their absorption, and use in bone formation.

J. S. H.

NOTES FROM LIGHTING RESEARCH LABORATORY, NATIONAL LAMP WORKS OF GENERAL ELECTRIC COMPANY.*

PROPORTION OF ENERGY RADIATED BY INCANDESCENT SOLIDS IN VARIOUS SPECTRAL REGIONS.[1]

By L. L. Holladay, Physicist.

THIS paper presents a speedy and accurate method of computing the portion of the total energy radiated by an incandescent solid in a given spectral region. The theory of the method is developed and specific data are presented on tungsten and several other types of incandescent radiators.

By combining Planck's equation for the spectral distribution of energy from a black-body radiator with Wien's displacement law connecting temperature T with the wave-length λ_m at which the maximum energy occurs, the proportion ϕ of spectral energy emitted from a black-body radiator at temperature T in the spectral region between wave-lengths zero and λ has been carefully computed. From a table and plot of these results, the proportion of energy in any region of the spectrum of a black-body at any temperature may be quickly determined.

It is further shown that if any incandescent solid of temperature T has the same distribution of energy in a given spectral region as a black-body radiator at temperature T_c (the color temperature of the incandescent solid), the proportion of radiant energy in this region of the spectrum of the incandescent solid at temperature T is G times as great as that from the black-body radiator at temperature T_c. If the total emissivity of the incandescent solid is ϵ_t at temperature T and if its color emissivity in the spectral region under consideration is ϵ_c (i.e., if ϵ_c is the ratio of energy radiated in the given spectral region by the incandescent solid at temperature

* Communicated by the Director.

[1] *Jr. O. S. A. and R. S. I.*, Vol. 17, November, 1928, p. 329.

T to the energy radiated in the same spectral region by a black-body radiator at temperature T_c) then the value of

$$G = \left(\frac{\epsilon_c}{\epsilon_t}\right)\left(\frac{T_c}{T}\right)^4.$$

Also, if l_1 is the luminous efficiency of the incandescent solid, and if l is the luminous efficiency of a black-body radiator at temperature T_c, the value of

$$\frac{G = l_1}{l}.$$

Several values of G are given for carbon, osmium, tantalum and tungsten radiators. Values of G for regions in the visible spectrum of incandescent tungsten are about 2.1 at a temperature of 1500° K., 1.52 at 2000°, 1.27 at 2500°, 1.16 at 3000° and 1.10 at 3500°. These values of G for tungsten are nominally correct only for regions in the visible spectrum, but are probably approximately correct for use in the ultra-violet regions as well.

VISION IN FIELDS BRIGHTER THAN THEIR SURROUNDINGS.

By P. W. Cobb and F. K. Moss.

PREVIOUS work has shown that vision is at its best when the visual object is seen in surroundings equal in brightness to its own; however, no investigation has been made of the limiting size of the surrounding field which is effective in this respect. In lighting practice it may be economically undesirable to maintain a uniformly high intensity of illumination over large areas, where a very high level of illumination is required on certain work. The purpose of the research abstracted here was to determine the limits within which an adverse effect on vision could be expected from the outlying area illuminated to a lesser intensity.

The visual test used was the precision with which a manually operated pointer could be kept in opposition to a similar pointer above it which moved slowly and irregularly from side to side. The two vertical pointers were separated

by a small vertical distance and as seen by the subject appeared in silhouette against a large white surface illuminated to a brightness of 10 millilamberts. The extent of the deviation from exact opposition was automatically recorded. The subject was seated in a darkened space, and viewed the pointers through an opening in one of a set of dark screens which exposed the white screen about the pointers to any desired area. The latter was varied in extent and the effect on vision was determined in each case. The table summarizes 400,000 settings of the manually operated pointer.

Extent of Illuminated Area Surrounding Pointers. Angle Subtended by Circular Area.	Corresponding Area in Sq. Ft. at Ten Feet.	Per Cent. Deviation from Mean Error in Setting Pointer.
6 Degrees	1	+ 4.2
11 Degrees	3	+ 1.8
18 Degrees	8	+ 3.0
31 Degrees	25	− 2.6
56 Degrees	90	− 3.5
77 Degrees	140	− 3.1

These data indicate that most of the disadvantage of dark surroundings, or outlying area, occurs when the bright central area is less than 25 sq. ft. at a distance of ten feet. This is equivalent to a circle 5.6 ft. in dameter at ten feet or 1.1 feet in diameter at two feet and subtending an angle of about 30 degrees. Between the smallest and largest fields used, there is a difference of about 7 per cent. in the precision of seeing. Whether such differences are significant in practice depends upon the requirements of the work. These data were taken at but one level of brightness, 10 millilamberts, corresponding to 11.6 foot-candles on a white surface of 80 per cent. reflection-factor. In practice with the low reflection-factors often found in work-places, 10 millilamberts may represent as much as 100 foot-candles or more. Therefore, the present data lie within the range of intensities of illumination used in lighting, and are conservative since the most distracting condition was used—that of a bright area sharply defined in dark surroundings. These data do not take into account possible physiological factors, such as eye-fatigue which cannot at present be measured quantitatively. How-

ever, our experience in this investigation leads us to believe that with good general lighting the spot of localized high-intensity illumination could be many times as bright as the surroundings without noticeable eye-discomfort provided the angular extent of the spot receiving localized lighting is about 30 degrees in diameter.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

OPTICAL SENSITIZING OF SILVER HALIDE EMULSIONS. I ADSORPTION OF ORTHOCHROME T TO SILVER BROMIDE.[1]

By S. E. Sheppard and H. Crouch.

THE absorption spectra in the visible and ultra-violet of Orthochrome T bromide have been measured in solvents and in water at various pH values. The adsorption of the dye to silver bromide was measured by mixing the two in various concentrations and then separating the phases. The grain-size frequency of the silver bromide was known so the calculation of the ratio of moles of dye per sq. cm. of surface of the grains could be calculated. Langmuir's adsorption equation was the only one found to fit the experimental determinations. As to the sensitizing of the silver bromide it is suggested that the dye is held to the bromide ion and that the photodecomposition is of an explosive character; thus one dye molecule could sensitize many silver bromide molecules.

NOTES ON MAKING DUPLICATE NEGATIVES.[2]

By C. E. Ives and E. Huse.

AFTER several years of experience, additional suggestions concerning the use of duplicating film have been made. The master positive should be as nearly as possible perfect in printing quality. A minimum density of 0.5 is necessary although overexposure should be avoided. The contrast of the master positive should be adjusted by the use of violet

* Communicated by the Director.

[1] Communication No. 337 from the Kodak Research Laboratories and published in *J. Phys. Chem.* **32**: *751. 1928; Phot. J.* **68**: *273. 1928.*

[2] Communication No. 356 from the Kodak Research Laboratories and published in *Trans. Soc. Mot. Pict. Eng.* **12**: *No. 34, 382. 1928; Amer. Phot.* **22**: *532. 1928.*

filters if necessary. Development should be complete but not excessive and should reproduce the contrast of the original exactly when printing is done through one violet filter (Wratten No. 39). Machine development is preferable to any other because it gives the uniformity that is required in duplication work.

The same quality considerations apply in making the duplicate negative. Contrast adjustments should not be made in the negative if they can be made in the master positive. When a duplicate negative of uniform printing density is required it is preferable to print it from a perfectly uniform master positive but if it becomes necessary to alter exposure in printing the duplicate negative, trial exposures should be made and tested by making final positives.

The printer for duplication work should give perfect uniformity of exposure and will give sufficient exposure if a 25-volt, 100-watt, concentrated filament lamp is used with an efficient relay condenser system or if a 300- or 400-watt lamp is used without condensers when printing speed is about 15 feet a minute.

LABORATORY HUMIDITY CABINET.[3]

By I. C. Matthews and A. M. Burgess.

AN air-conditioning cabinet, designed to give temperatures and humidities approaching tropical conditions, for use in conducting a tropical weathering test on metals, photographic and other materials, is described. As improvements over existing apparatus of this nature, several features of construction are mentioned. These include (1) a box properly constructed of alberene stone which is corrosion resistant and a fair non-conductor of heat; (2) all parts which are exposed to moisture are made of copper or brass; (3) a thermostatically controlled steam coil is used as the heating unit; (4) the diaphragm valves are automatically operated by a recording and controlling instrument; and (5), all hangers and supports for holding articles to be tested are made of glass. Two photographs and a detailed drawing are included.

[3] Communication No. 345 from the Kodak Research Laboratories and published in *Ind. Eng. Chem.* **20**: *1239. 1928.*

THE FORMATION OF THE PHOTOGRAPHIC LATENT IMAGE.[4]

By S. E. Sheppard.

AN introductory portion reviews latent image and sensitivity theories. It is pointed out that the balance of evidence leads to the conclusion that the latent image consists of development centers composed chiefly of colloidal silver. These centers are formed by photochemical reduction at pre-existing sensitivity nuclei. These nuclei sensitize for light but not for X-rays, and are furnished by gelatin. They probably consist of silver sulfide, or silver, or both substances, in specks too small to induce developability.

The crystalline character of the silver halide grain implies a certain lattice energy. It is shown that this enters into the initial energy required to shift an electron. This initial energy quantum is much greater than that of photographically active light. Consequently, if the primary photochemical change is

$$\begin{aligned} &- \\ &Br + h\nu = Br + \theta \\ &+ \\ &Ag + \theta \rightarrow Ag \text{ (Met)} \end{aligned}$$

then the silver bromide first reduced cannot be under normal lattice constraints.

Investigations (with Dr. Vanselow) of the photo-potentials of silver: silver bromide electrodes in potassium bromide solutions demonstrate that electrons and bromine are released together by light acting on silver bromide. The potential change consists of an initial inertialess negativization passing over into a positivization. The positive potential rise can be reduced or eliminated by bromine acceptors, or replaced by bromine diffusion. It is concluded that the inner photo-electric effect occurs at sensitizing interfaces where the silver halide is disoriented. The formation of the latent image may be interpreted as a concentration effect, caused by orientation of sensitizing specks and silver halide at the

[4] The Sixth Hurter and Driffield Memorial Lecture, Communication No. 359 from the Kodak Research Laboratories and published in the *Phot. J.*, **68**: *397. 1928.*

interfaces. It is shown that the orientation hypothesis is adequate to explain the transition between general and optical sensitizing by silver sulfide, silver, or similar nuclei. As the number of nuclei per grain increases, and their size diminishes, the general sensitizing (concentration effect) decreases, the optical sensitizing (wave-length shift) increases. The special features of reciprocity failure and incomplete summation are also accounted for. Thus the existence of threshold intensities is deducible from deficiency of nucleus concentration for poorly sensitized grains. The existence of an optimum intensity is also explained by dispersity considerations. As the light intensity is increased, i.e., the quantum density, so is the chance of formation of new, independent nuclei competing with pre-existent ones in latent image concentration. At very high intensities, therefore, the grain acts more as with X-rays, where pre-existent nuclei are ineffective.

THE FRANKLIN INSTITUTE.

(*Proceedings of the Stated Meeting Held Wednesday, November 21, 1928.*)

THE Stated Meeting of the Institute was called to order at eight-fifteen p.m. by the Acting President, Mr. Henry Howson.

The Secretary reported that the minutes of the October meeting had been printed in full in the Journal of the Institute for November, and moved that they be approved as printed. The motion was seconded and unanimously adopted and the minutes were declared approved.

The Secretary presented the following report concerning membership changes since the last report: Eight new Resident members, three new Non-Resident members, one new Student member; one death.

There being no further business, the Chairman introduced as the speaker of the evening Captain Hiram B. Ely, Ordnance Department, United States Army who spoke on the subject of "Aircraft Detectors and the Anti-Aircraft Problem."

The meeting adjourned at nine-forty p.m., with a rising vote of thanks to Captain Ely for his interesting and instructive paper.

HOWARD MCCLENAHAN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of Stated Meeting held Wednesday, November 7, 1928.*)

HALL OF THE COMMITTEE,
PHILADELPHIA, November 7 1928.

DOCTOR GEORGE S. CRAMPTON *in the Chair.*

The following report was presented for final action.

No. 2883: Monroe Calculating Machine.

The growth in the use of different forms of calculating machines has brought many of them before the Committee on Science and the Arts for investigation. One of the first of these was a calculating machine invented by F. S. Baldwin in 1874 for which he was awarded the John Scott Medal.

Since that time six machines of other inventors have been awarded the Scott Medal for either calculating or adding machines.

The present form of the Monroe machine includes the many improvements, that have been made on the Baldwin Machine in the past fifty years until the arithmetical operation of addition, subtraction, multiplication, division and their various modifications are carried on with surprising quickness and accuracy.

One notable improvement is that of adding a series of numbered keys by the use of which multiplication can be carried on automatically.

In order to multiply a number by 37, for example, this number is first set on the keyboard and on depressing the plus key it appears in the lower of two horizontal dials while in an upper dial the figure 1 appears showing that the num-

ber has been taken once. On depressing the multiplying key numbered 6 the given number is added continuously six times and the number 7 appears on the upper dial, the product of 7 times the number appears in the lower dial. The carriage of the machine also moves from the units place to the tens and on depressing multiplying key 3 the number is multiplied by 3 tens or 30 making the entire multiplier 37, that number showing on the upper and the product showing on the lower dial. Automatic division can also be carried on. The machine in its most recent form is driven by an electric motor and is a most satisfactory aid in calculation.

The following reports were presented for first reading:

No. 2895: Masonite and Presdwood.

No. 2896: Gyro-Pilot.

No. 2897: Work of Mr. William H. Gartley in the Gas Industry.

GEO. A. HOADLEY,
Secretary to Committee.

THE JAMES MAPES DODGE FOUNDATION CHRISTMAS WEEK LECTURES FOR YOUNG PEOPLE.

THE Institute announces that we have invited Professor A. S. Eve, Director of the Department of Physics, McGill University, to be our Christmas Week lecturer for the present year. Dr. Eve will deliver three lectures on "Things that Spin; Things that Swing; Things that Wave," on December twenty-sixth, twenty-seventh and twenty-eighth, at three P.M., in the Hall of the Institute. The members of the Institute are reminded of these lectures and are requested to call them particularly to the attention of the young members of their families, and to other young people of school age. A ticket to the series should be regarded as a fitting Christmas present by any young person of intellect. Tickets can be procured through the Controller's Office. Price for the series: two dollars.

HOWARD MCCLENAHAN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(*Stated Meeting, Board of Managers, November 9, 1927.*)

RESIDENT.

MR. EDGAR W. BAIRD, Manufacturer, 2114 Sansom Street, Philadelphia, Pa. For mailing: Chestnut Hill, Philadelphia, Pa.

MR. GEORGE W. EYRE, Insurance Broker, 311 Finance Building, Philadelphia, Pa. For mailing: 3732 Locust Street, Philadelphia, Pa.

MR. WILLIAM B. FOULKE, Salesman, 424 Land Title Building, Philadelphia, Pa. For mailing: Bowling Green, Media, Pa.

MR. ALBERT HERBST, Manager, 1233 Rising Sun Avenue, Philadelphia, Pa.

MR. T. MAXWELL MERYWEATHER, Yarn merchant, 460 Drexel Building, Philadelphia, Pa. For mailing: Spring Lane, Chestnut Hill, Philadelphia, Pa.

MR. JOSEPH N. PEW, JR., Vice-President, Sun Oil Company, Finance Building, Philadelphia, Pa.

MISS ELIZA SMITH STECK, Teacher, Ogontz School, Ogontz, Pennsylvania.

MR. WILLIAM M. STILWELL, JR., Sales Engineer, 1600 Arch Street. In care of Dingle Clark Company, Philadelphia, Pa.

NON-RESIDENT.

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BOOK REVIEWS.

THÉORIE IONIQUE DE L'EXCITATION DES TISSUS VIVANTS. Par le Professeur Docteur P. Lasareff, Membre de l'Académie des Sciences de Leningrad, Directeur de l'Institut de physique et de biophysique de Moscou. x–240, pages, 25 x 16 cm., paper. Librairie Scientifique Albert Blanchard, Paris, 1928. Price, 40 francs.

Every manifestation of a physical phenomenon, however elaborate and precise the method employed in its observation, must finally be translated with some physiological action. The senses which are the final indicators are generally applied without much thought of the functioning of the mechanism through which stimulating effects are perceived, and a closer study of the subject is of more than passing interest in physical science. The work is in that field of biophysics in which a searching analysis is made by purely physico-chemical methods, of the capital rôle of ions in the phenomena of excitation of nerves and of muscles. With its many graphs and mathematical deductions the work resembles more a treatise on mathematical physics than one on a biological subject.

After developing the theory of excitation and establishing quantitative laws of the phenomena of the excitation of living tissue, those principles are applied to a consideration of the theories of vision, audition, touch and olfaction. Of particular interest to the physicist are the treatment of the theory of vision, color-sensation, persistence of vision, and other topics of a physiological nature which have already claimed his attention. The work is a model of logical analysis and thoroughness. It is thoroughly documented and contains many quotations in the language of their source (mostly German). Including the results of researches in the author's laboratory as late as 1927, the text is as fully up-to-date as can be reasonably be expected. A previous edition appeared in German in 1923. Those who would analyze the mechanism and its action of physical stimulus and resulting perception will not regret the effort for a perusal of this book.

L. E. P.

A SURVEY OF NITROCELLULOSE LACQUER. By Bruce K. Brown (Formerly with Commercial Solvents Corporation) and Francis M. Crawford (Director of Patent and Research Information Departments, Commercial Solvents Corporation). 308 pages, 8vo. New York, The Chemical Catalog Company, Inc., 1928. Price, $7.50.

With the exception of a few pages of explanatory matter and some historical outlines this work consists of the list of patents taken out in the principal countries, and also a long bibliography and an index of materials named in the patents. It represents an enormous amount of labor and shows vividly the great industrial importance that these products have acquired. Their use has been enormously increased in connection with the automobile industry but the manufacture of nitrocellulose lacquer was well advanced many years ago. The development of aviation also stimulates greatly the manufacture of such materials. The comparison of the use of the materials for automobile lacquering is shown by the fact that in 1923 less than one per cent. of the automobiles made in the United

States were so treated, but in 1927 nearly one hundred per cent. were lacquered. This extensive adoption of this procedure followed the results of laboratory tests which showed the durability of the material. In the introductory text much information is furnished as to the nature of these products, and the principles on which they are produced and applied as well as a comprehensive account of the several types.

HENRY LEFFMANN.

INDUSTRIAL CHEMISTRY—AN INTRODUCTION, AN ELEMENTARY TREATISE FOR THE STUDENT AND GENERAL READER. By Emil Raymond Riegel, Ph.D., Professor of Physical and Industrial Chemistry, University of Buffalo. 649 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1928. Price, $9.

Many books of this type are before the public. It is an interesting and important subject, the extent of which is such that a very large volume can be prepared if author and publisher are willing. The present work is intended to be a compact account of the large number of industrial procedures in which chemistry has a dominant position. As the author remarks in the preface, the industry is constantly changing, what seemed like a fantastic idea yesterday is realized today. The progress of invention and discovery is constantly influencing the operative conditions. The author notes for instance the importance that the production of radium from Colorado ore had attained making the United States one of the principal sources of this important element; today the Colorado mines are closed, the rich mineral from the Belgium Congo dominating the market. The fusel oil industry was hurt by the adoption of prohibition, but the production of butyl alcohol made by fermentation took its place, but this latter is threatened by the synthetic process. The time-honored industry of the production of methanol by distilling wood is threatened with the extinction by the manufacture of it from water gas. Even more serious changes are indicated. Chile depends in very large part for its operating income upon the export duty on nitrates. The artificial production of ammonia which can be very easily converted into nitric acid threatens the natural sources. Similarly the great advance in the rayon industry may seriously injure the silk production of Japan.

Concerning the general character of the work it is only to be said that it is of the type of the works in this field. It contains a very large amount of information and great variety of topics. It is well illustrated and the chemical principles involved in the process are set forth in detail. Undoubtedly the making of books is an expensive method, but taking into comparison other works of similar size and character the reviewer is not entirely clear as to the necessity for the high price of the book.

HENRY LEFFMANN.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 287. Theories of Flow Similitude, by A. F. Zahm. 10 pages, illustrations, quarto, Washington, Government Printing Office, 1928, price five cents.

The laws of comparison of dynamically similar fluid motions are derived by three different methods based on the same principle and yielding the same or

equivalent formulas. In this report prepared for publication by the National Advisory Committee for Aeronautics, in June, 1927, are outlined the three current methods of comparing dynamically similar motions, more especially of fluids, initiated respectively by Newton, Stokes (or Helmholtz), and Rayleigh. These three methods, viz., the integral, the differential, and the dimensional, are enough alike to be studied profitably together. They will presently be treated in succession, then compared.

Report No. 291. Drag of C-Class Airship Hulls of Various Fineness Ratios, by A. F. Zahm, R. H. Smith, and F. A. Louden. 16 pages, illustrations, quarto. Washington, Government Printing Office, 1928, price ten cents.

This report presents the results of wind tunnel tests on eight C-class airship hulls with various fineness ratios, conducted in the Navy Aerodynamic Laboratory, Washington. The purpose of the tests was to determine the variation of resistance with fineness ratio, and also to find the pressure and friction elements of the total drag for the model having the least shape coefficient.

Seven C-class airship hulls with fineness ratios of 1.0, 1.5, 2.0, 3.0, 6.0, 8.0, and 10.0 were made and verified. These models and also the previously constructed original C-class hull, whose fineness ratio is 4.62, were then tested in the 8 by 8 foot tunnel for drag at 0° pitch and yaw, at various wind speeds. The original hull, which was found to have the least shape coefficient, was then tested for pressure distribution over the surface at various wind speeds.

R.

ENAMELS: THEIR MANUFACTURE AND APPLICATION TO IRON AND STEEL WARE. By Laurance R. Mernagh. 234 pages, illustrations, plates, diagrams, 8vo. London, Charles Griffin and Company, Philadelphia, J. B. Lippincott Company, 1928. Price, $7.

The making of hollow ware for culinary and sacrificial purposes is a very early handicraft. Archeologists rely very largely upon the pottery "finds" for judgment as to the age and civilization of primitive peoples. Clay was, of course, the primitive material, but when man began to obtain in some quantity the baser metals, these replaced the clay to a great extent. The liability of iron to corrosion constitutes a great interference with its use and several methods have been extensively adopted to prevent this. Tinning and zincing (the latter universally, but erroneously, known as galvanizing) have been familiar for a long while. Each has its drawbacks. Enameling, that is the coating of the metal with some resistant non-metallic material, has secured wide vogue. The methods have not by any means been free from objection, for certain metals included in the enameling mixture, such as lead, antimony and arsenic render the food cooked therein liable to be seriously contaminated. The action of health authorities has to a great extent eliminated this danger. Enameled ware is now threatened with a new competition, the use of aluminum. This competition has given rise to a charge that aluminum is taken up in the food and the manufacturers of that ware have been busy of late in defending their product.

The work in hand is largely devoted to British methods and the author frankly admits that British practice in this field is not dominating and that America and

Germany are far in advance in both practical and scientific development. Nevertheless, he is evidently familiar with the literatures of both these nations and has included such knowledge in the text, which is comprehensive and clear. It begins with the preparation and treatment of the metal basis, then discusses in fullness the raw materials of the enamels, their formulas, preparation and application. Defects and difficulties are fully set forth and the remedies indicated. It is worthy of note that the British enameling industry which had taken a spurt during the late war, languished thereafter for lack of tariff protection, but this has now been granted a duty of twenty-five per cent. being imposed on imported enameled hollow-ware.

An indication of the listlessness of British manufacturers in the matter of research is indicated on page 14, relating to proprietary substances recommended for picking, it being said that these cost much more than their value. It seems that the larger establishments should consult chemists about this and while exact data might be difficult to obtain good clues would certainly be secured and further experiment would place the user independent of the proprietary products. It is doubtful if the discussion of opacity on pages 45–48 is satisfactory to the general reader.

The book is well printed in clear type with numerous illustrations including plates representing microscopic appearances of the metal-base, machinery and graphs.

HENRY LEFFMANN.

A FIRST COURSE IN PHYSICS FOR COLLEGES. By Robert Andrews Millikan, Ph.D., Sc.D., Director of the Norman Bridge Laboratory of Physics, Pasadena, California; Henry Gordon Gale, Ph.D., Professor of Physics in the University of Chicago; and Charles William Edwards, M.S., Professor of Physics in Duke University. xiii–676–xlii pages, 96 illustrations, 583 figures and 25 tables, cloth 8vo. Boston, Ginn and Company, 1928. Price, $3.72.

The title of this volume, "A First Course in Physics for Colleges," indicates the primary reason for its inception. In the preparation of this course the authors strove to produce a text which might be given in its entirety to first-year college students. To attain such an end and yet not fail to include all the important principles of physics and their corresponding applications in everyday life, the authors have labored in co operation with other teachers for a considerable number of years. In this respect the book fulfils a long-felt need of freshmen instructors who often are required to assign the more elementary sections in advanced texts. The chapters, thirty-nine in number, cover practically every phase of physical study. Particularly might be mentioned those dealing with conduction of electricity through gases, electrical radiations and radioactivity. At the end of the chapters a number of solved problems, problems for solution and test questions are to be found. A list of supplementary problems will be found in appendix A, while appendix B consists of a number of tables showing conversion factors, properties of solids, liquids and gases, heats of combustion, refractive indices, etc. A most noteworthy feature is that the book contains over ninety portraits of physicists and illustrations of recent achievements in physics. Throughout the text examples are given illustrating the application of physical principles to recent well-known inventions. A few of these are the

Flettner rotor ship, the Sperry gyrocompass, the vacuum tube, the Coolidge X-ray tube and so forth. One glaring mistake appears to have crept in unnoticed. The statement is made that niton, the transformation product of radium, becomes a liquid at 150° C. According to the International Critical Tables the normal boiling point is − 61.8° C.

The book is written in an exceedingly clear style and is so well illustrated that anyone earnestly desiring to improve in an elementary way his or her knowledge of the whole field of physics will find its perusal a source of interest and pleasure.

T. K. CLEVELAND.

HEAVISIDE'S ELECTRICAL CIRCUIT THEORY. By Louis Cohen, Ph.D., Consulting Engineer, Professor of Electrical Engineering, George Washington University, with an introduction by PROFESSOR M. I. PUPIN. ix–169 pages, illustrations, 8vo, cloth. New York, McGraw-Hill Book Company, Inc., 1928. Price, $2.50.

Heaviside, in his Electromagnetic Theory, which appeared in 1899, introduced some novel applications of operational methods in the analysis of transient electrical phenomena which he derived by more or less unconventional methods. The validity of his results was established rather by a process of experimental analysis guided by the intuition of a physicist of exceptional vision than by rigorous deduction. His demonstrations were not easily followed and the difficulty of verifying the general truth of his theorems for many years militated against the wide application that the true merit of his work deserves. Renewed interest in Heaviside's methods awakened by the growing importance of transient electrical phenomena has stimulated in recent years a searching study of his work by several investigators of note with the result that much of the uncertainty of the theory in its original form disappears. The algebraic properties of symbols of derivation are discussed at considerable length including a note on operators with fractional exponents, in that unique work by the late John Perry, "Calculus for Engineers" which appeared in 1897. It is not surprising that a consideration of the operational method should be found in Perry's work for Heaviside quotes him freely in the introductory chapters of the second volume of his Electromagnetic Theory and doubtless the mathematical methods of both authors were mutually familiar. Doctor Cohen's treatise brings the subject within the reach of average technical readers. He explains the Heaviside methods in straightforward understandable mathematical language. The salient feature of the work is the derivation of the famous "expansion theorem" which "applies to all kinds of circuits, concentrated inductances and capacities, or distributed inductances and capacities, giving directly the solution for current and voltage distribution in the circuits; the steady as well as the transient state. Of course, its greatest utility is in the facility it affords for obtaining solutions for transient effects, which may be in some cases very difficult if not altogether impossible to obtain by the usual methods." This derivation is made step by step with meticulous explanation, first for unidirectional electromotive forces, then for alternating electromotive forces. Many applications are worked out at length for a variety of circuits followed by chapters in which the expansion theorem is applied to filter circuits, ocean cables, transmission lines, and artificial lines.

In a final chapter, an analytical examination is made of Heaviside's own derivation of the expansion theorem. An appendix includes a note on Bessel functions, an assemblage of the mathematical formulas used in the text, tables of Bessel functions, hyperbolic functions, and of the error function. Dr. Cohen has left little undone to bring Heaviside's method of dealing with difficult problems of electrical circuits and analogous problems within the reach of every engineer.

L. E. P.

COLLOID SYMPOSIUM MONOGRAPH. Papers presented at the Sixth Symposium on Colloid Chemistry, University of Toronto, June, 1928. Edited by HARRY BOYER WEISER, Professor of Chemistry, The Rice Institute. 341 pages, illustrations, 8vo. New York, The Chemical Catalog Company, Inc., 1928. Price, $6.50.

Researches in colloid chemistry continue unabated, indeed with increasing force. A system of annual collaboration at American universities has been enforced for several years and the present volume presents a considerable list of papers covering many phases of the physical chemistry of colloidal forms of matter. The general tenor of the communications is of course fairly the same in the several volumes, but the scope of colloid chemistry is so wide and penetrates into the many fields of pure and applied science that each volume shows notable variety. The present volume deals rather largely with vital phenomena and the opening essay on "Living Matter" by Sir William B. Hardy endeavors to throw some light upon the complex problem of life in its various forms. Many details are brought forward and among the conclusions is the statement that biology is in urgent need of real physicists. It might also be said that biology is in need of a broader interest in natural history that is, that the biologists should be something more than the laboratory workers with a few organisms.

The great variety of subjects treated in this volume will make it of use to chemists in many fields, both practical and theoretical. As a closing suggestion of Hardy's paper the following extract will be interesting to teachers:

"Let me give you my ideal of a Biological College. It should have three floors—a ground floor for molecular physics, a first floor for biophysics, and a top floor for cell mechanics. And of the staff the professor of molecular physics should have no responsibility for biology, the professor of biophysics should be a Mr. Facing-both-ways, responsible to physics and to biology, whilst the professor of cell mechanics should be a biologist pure and simple. That college I should expect to provide the new synthesis of knowledge of which biology stands in need."

HENRY LEFFMANN.

CURRENT TOPICS.

Solid Carbon Dioxide. The use of solid carbon dioxide or "Dry-Ice" as a refrigerant is described by REBEKA DIERZ (*The Forecast*, 1928, *36*, 79–80, 128). Dry-Ice is compressed carbon dioxide snow. Its value as a refrigerant depends on ease of control, uniform temperature, absence of moisture, and mobility. Its greatest success has been in the refrigeration of perishable foods, especially in small packages during transportation. It has not yet been applied to household refrigeration. J. S. H.

Greenness and Vitamin A in Plant Tissue. JOHN W. CRIST and MARIE DYE of the Michigan State College of Agriculture and Applied Science (*Scientific Mo.*, 1928, *27*, 166–171) have tested the relative nutrient values of green vegetables and bleached vegetables by means of animal experiments. They recommend that, when the leafy portions of a vegetable are used as foods, green leaves should be preferred to bleached leaves. Apparently some connection exists between the greenness and the vitamin A content. Their recommendation holds true for such vegetables as lettuce, cabbage, celery, and asparagus.

J. S. H.

Electrochemical Oxidation of Benzene to Quinone. HAROLD EMORY FENIMORE (Thesis, Graduate School, Univ. of Penn., 1928, 1–24) has devised a new anode electrolyte, involving the use of acetone as the solvent in the electrochemical oxidation of benzene to quinone. Cold benzene extraction has been found the most efficient method for the extraction of the crude quinone from the anolyte. The crude product may be purified either by volatilization in a rapid current of steam or by selective solubility in petroleum ether.

J. S. H.

Stabilization of Cupferron Solution. FREDERICK G. GERMUTH (*Chemist Analyst*, 1928, *17*, no. 3, 3, 15) recommends the use of phenacetine (acetylphenetidine) as a stabilizer for the solution of cupferron (aminonitrosylphenylhydroxylamine) which is used as a reagent in analytical chemistry. He finds that addition of 0.05 gram of phenacetine to each 100 cc. of the cupferron solution causes that solution to retain its original value as a precipitant for a period of 20 to 30 days.

J. S. H.

Transition Temperature of Carbon Tetrachloride. JAMES E. MCCULLOUGH and HARRIS E. PHIPPS of Oberlin College (*Jour. Am. Chem. Soc.*, 1928, *50*, 2213–2216) have determined that pure solid carbon tetrachloride passes from the cubic to the monoclinic system at a temperature of $-48.54 \pm 0.02°$ C. The hold in the time-temperature curve at this transition point has approximately the same duration as that at the freezing point. This transition point is suggested as a fixed point in thermometry.

J. S. H.

Atomic Weight of Cesium. THEODORE W. RICHARDS and MARCEL FRANÇON (*Jour. Am. Chem. Soc.*, 1928, *50*, 2162–2166) have purified the cesium alums by recrystallization, and then converted them into cesium chloride. Analysis of the cesium chloride by comparison with silver has given the value 132.81 for the atomic weight of cesium.

J. S. H.

Formic Acid. ALBERT SPRAGUE COOLIDGE (*Jour. Am. Chem. Soc.*, 1928, *50*, 2166–2178) has determined the vapor density of formic acid which probably was 99.99 per cent. pure. The results indicate that the vapor is an ideal mixture of two gases, having single and double molecules, respectively.

J. S. H.

Infra-red Absorption by the Sulphydrate Group. JOSEPH W. ELLIS of the University of California (*Jour. Am. Chem. Soc.*, 1928, *50*, 2113–2118) has determined the infra-red absorption spectra of several alkyl and aryl mercaptans and sulphides, using a recording quartz spectrograph. The mercaptans are characterized by a single absorption band at 1.99 to 2.00 microns, which is not given by the corresponding sulphides. This band and another band, which occurs at 3.8 to 3.9 microns, are considered to be due to the presence of the sulphydrate (—SH) group, radical, or bond.

J. S. H.

Electricity Produced by the Friction of Glass with Solid Elements. P. E. SHAW AND C. S. JEX. (*Proc. Royal. Soc.*, A 779.) To get reliable data of the sign and quantity of the electrical charge caused by rubbing two solids together it is necessary to have materials of known composition and physical structure and of definite surface cleanliness. The rubbing should be done by machine to assure uniformity of method. Glass surfaces were cleaned by boiling in chromic or nitric acid for 15 minutes or an

hour respectively and by washing subsequently with boiling water for long periods, even for as much as eight hours. The surfaces of metals were prepared by scraping before each rub with a steel blade newly cleansed in a Bunsen flame. The sign and amount of charge developed were obtained from the charge induced in a sheet of metal beside the glass rod of the experiment. After each rub the two bodies concerned were earthed, the deflection of the electroscope joined to the inductor having been read.

"Some elements never, with any type of glass surface tried, showed negative charge. These are C, Cd, Fe, Pb, Bi, Ag, Cu, Pt, Mg, W. Other elements show ultimate negative charge. These are Zn, Sn, Al, Sb, Ni, Co, Se, As, Cr, Tl, S." It was often the case with the latter group that a positive charge was produced by the first rubs. With the repetition of the rubbing this finally was converted into a negative charge. In every instance of this group the first charge produced was negative when the glass used had been recently fused.

An interesting promise is made: "We shall show in the next paper that in the case of three solids (A, B, C) A may be positive to B; and B to C; and yet C be positive to A. This may occur when the bodies are of different classes, say, metal, textile, glass, which have different physical and chemical characteristics."

G. F. S.

X-Radiation from Gases. A. BJÖRKESON. (*Nature*, July 7, 1928.) In 1924–25 the author, working in the Norman Bridge Laboratory, tried in vain to get X-rays from gases. Now he reports success from Upsala. A beam of electrons was directed on a hole in the upper part of a crucible placed in a vacuum. The heating of the crucible by the bombardment evaporated metallic sodium contained therein. As the vapor rose through the hole it was struck by the electrons and made to emit X-rays. These were detected by their effect on a photographic plate put near the crucible. The rays had access to the plate only through a small hole in a brass sheet, thus producing an effect as in a pinhole camera. The part of the plate corresponding to the stream of vapor was blackened but this change was absent from that portion of the plate when the sodium was removed from the crucible.

When sulphur replaced sodium even more conclusive results were obtained. An electric heater evaporated the sulphur independently of the beam of electrons. The strength of the electron current was 90 ma., and the electric tension 6,000 volts. The X-rays from the sulphur passed through a slit .6 mm. wide into a vacuum spectrograph and fell on a gypsum crystal acting as a

grating. After an exposure of two hours 5 lines appeared on the photographic plate. The two strongest of these correspond to the K_α and K_β lines of sulphur. The others were too weak to have their wave-lengths determined. The comment of the investigator is "So far as I know, this is the first time an X-ray spectrum has been obtained with a gas as radiator."

G. F. S.

Engine Knock and Related Problems. A. C. EGERTON. (*Nature*, July 7, 1928.) Since knocking limits the compression in the internal combustion engine, it reduces the efficiency attainable. "If the compression ratio were raised from 4 to 6 there would be a gain in efficiency of nearly 20 per cent. The world's production of petrol is of the order of 12,000 million gallons per year. A gain of 20 per cent. on the efficiency might save more than 2,000 million gallons of petrol." The addition of benzene, toluene, xylene, etc., to gasoline has long been known to reduce knocking, but to elevate the compression ratio from 4 or 5 to 6 would require the volumes of gasoline and benzene to be equal and the world does not produce sufficient benzene. Midgely and Boyd in their search for some compound more suitable than benzene examined thousands of chemicals and found lead tetra-ethyl. In a Ricardo variable compression engine knocking begins with gasoline alone when a compression ratio of 4.9 is attained. The presence of .1 per cent. by volume of lead tetra-ethyl permits the ratio to reach 5.7 per cent. "About one part of lead tetra-ethyl in 1,500 parts of petrol (about 5 c.c. of ethyl fluid per gallon) will permit the use of a compression ratio up to 6.1, and give an increase of at least 10 per cent.in the power thereby. Furthermore, if all petrol were to be treated with such a 'dope,' it would be quite feasible from the point of view of supply, because it would entail about 40,000 tons of lead per annum, which is not more than 2 per cent. of the world's production of that metal. One molecule of lead in 200,000 molecules of fuel-air mixture is definitely effective."

In the experimental work it was first established that anti-knocks do not influence the location of the detonation of the gaseous mixture. Another line of attack was followed. Weerman had found "that the igniting temperature of petrol, when dropped into a heated iron pot through which air was gently blown, was very considerably raised by the presence of anti-knocks." Mr. Egerton found no elevation of temperature to result from the introduction of lead oxide into the pot but lead vapor raised the temperature considerably "and to much the same extent for a given amount of lead introduced as when introduced as lead tetra-ethyl in solution in

petrol. So the lead part of the molecule dissociated from the ethyl molecule was essentially the active constituent." Other volatile elements were thereupon examined. Al, Mg, Hg, I, P, Au, and Zn proved ineffective while Fe, Ni, Mn, Bi, Se, Tl, Na, Cd, Ca, and Sb caused the rise of temperature. Thallium was, however, the most effective of all and potassium also ranked very high. "It is the metal part of an organo-metallic anti-knock which is mainly instrumental in the action. This metal atom must be in an incipient state of oxidation." That is, the oxide must not exist in relatively large masses.

What is the effect of the anti-knocks on the vapors about to unite? "Anti-knocks definitely slow down the rate of reaction prior to ignition, as curves showing the temperature rise indicate. We have come to the conclusion that ignition starts, not at the surface, but in centers of high energy in the body of the gas. The anti-knock delays combustion not specially at the surface, but by inhibiting the rate of oxidation prevents the setting up of these centers." A table is given of the rise of ignition temperature produced by lead tetra-ethyl. No rise occurs with amyl alcohol, dimethylaniline and carbon disulphide. With benzene it is 18°, with pentane 75°, with valeric aldehyde 380° C. "The combustion of normal paraffin hydrocarbons (which are those constituents of petrol that are most prone to knocking), is more inhibited than that of naphthalenes, for example, such as cyclohexane. Further, there is a very remarkable inhibition of the combustion of aldehydes." "In what stage of affairs in the engine do the anti-knocks have effect? It was found that preliminary oxidation during the compression stroke was much less when inhibitors were present than when they were not present. It was clear that anti-knocks act on the gaseous charge in the stage prior to ignition (and prior to inflammation at the flame front), and delay the initial stages of reaction."

"Knocking appears to be due to inequality in the condition of the charge set up, particularly in regions of high pressure and temperature, as in the neighborhood of hot exhaust valves. This inequality provides regions of high energy, containing molecules in high energy states, where reaction can spread more quickly. Unequal burning gives rise to a vibratory condition of flame. Any influences, such as a higher state of turbulence or cooler surfaces or more even or longer combustion space, which tend to prevent sudden and local rise of pressure, and the setting up of centers of high energy, tend to prevent knocking. Anti-knocks, such as lead ethyl, by inhibiting the processes of combustion which we have seen to occur in those centers, are therefore effective in preventing knocking.

Furthermore, they have been rendered effective by the temperature and oxidation to which they and the charge are exposed during the compression stroke; the charge in the engine cylinder is so affected by its previous exposure to oxidation that the opportunity for a flame to meet regions in a high state of energy is greater than when those previous oxidations have been appreciably inhibited by anti-knocks or other factors."

G. F. S.

The Constitution of Germanium. F. W. ASTON. (*Nature*, August 4, 1928.) By using accelerated anode rays the mass spectrum of germanium was photographed five years ago. From the feeble effects then produced it was possible to identify its three chief isotopes, 70, 72, and 74. Recently volatile compounds of the element obtained from Prof. Dennis of Cornell made it possible to make more accurate determinations. With germanium tetraethyl the three lines previously photographed appeared accompanied by 5 fainter new lines. The isotopes are 70(*c*), 71(*g*), 72(*b*), 73(*d*), 74(*a*), 75(*e*), 76(*f*), 77(*h*), the letters indicating rank in intensity. "It will be noted that of all these mass numbers two only, 72, 73 are peculiar to germanium; the others all form isobaric pairs with the neighboring elements zinc, gallium, arsenic and selenium."

G. F. S.

Caustic Soda Treatment Improves Joint Strength of Certain Woods when Glued. (U. S. Department of Agriculture.) Treating with caustic soda certain species of wood which frequently produce weak or inferior joints when glued into doors, furniture, airplane propellers, and similar articles, improves the strength of these joints, experiments made by the Forest Products Laboratory, Forest Service, show.

A 10 per cent. solution of caustic soda gave the best results as a treating material in the laboratory's tests. Joints of hard maple, yellow birch, white oak, red oak, red gum, black cherry, basswood, and osage orange wood treated with caustic soda showed a decided improvement in strength over joints of untreated wood. While caustic soda solutions weaker than 10 per cent. improved the strength of joints they were not so effective as the 10 per cent. solution.

In the tests made by the laboratory the wood surfaces to be joined were brushed with the caustic soda solution, and after a period of 10 minutes were wiped with a cloth to remove any excess solution or dissolved material, and were then allowed to dry before they were glued. The same grade of glue was used and the density

of the wood tested was substantially the same in every case. When the blocks of wood had been conditioned for 10 days they were cut into specimens of the proper size and their strength tested by a special machine devised for the purpose.

The effect of the caustic soda treatment in improving the strength of glued joints was especially pronounced in certain woods in which "starved joints," those in which the film of glue between the wood surfaces is not continuous, are ordinarily produced, and is well illustrated by the results obtained in the tests of hard maple glued with animal glue. The shearing strength (measure of the capacity of wood to resist slipping of one part upon another along the grain) of a piece of untreated wood glued under favorable conditions was 3,110 pounds, as compared with 1,570 pounds for an untreated piece in which starved joints were manifest, and 3,250 pounds for a piece treated with caustic soda solution, but glued under the same starved-joint conditions. It is quite evident, of course, from these figures that the joints of treated wood were the strongest.

Osage orange wood treated with caustic soda and glued with casein glue showed a shearing strength of over 3,000 pounds, as compared to a shearing strength of only 294 pounds exhibited by the joints of untreated wood. This is an even more striking illustration than the hard maple.

Although the laboratory has experimented with other materials such as ammonia, benzol, hydrochloric acid, bleaching powder, hydrated lime, oxalic acid, and formaldehyde, none of these has been found so satisfactory as caustic soda for treating wood intended for gluing purposes.

Just why treating certain woods with caustic soda increases their joint strength when glued is not known. Evidently, the caustic soda changes the surfaces of the wood fibers in such a way as to cause the glue to stick more firmly.

Attention is called by the laboratory to the fact that while the caustic soda treatment has been found effective in improving the strength of joints produced with certain woods and glues, its use is recommended only where equally good results are unobtainable with standard gluing practice.

Toxic Action of Ethylene Dibromide. In the course of a study of ethyl gasoline by the United States Bureau of Mines, B. G. H. THOMAS and W. P. YANT (*Pub. Health Rep.*, 1927, *42*, 370–375) investigated the action of ethylene dibromide on animals. This compound, which is a volatile liquid with a chloroform-like odor, occurred in the ethyl gasoline in the ratio of 2 cc. per gallon.

Ethylene dibromide was sufficiently toxic to kill guinea pigs and rats, but its minimum lethal dose was not determined. Guinea pigs were made to breathe air containing ethylene dibromide vapor for 1 hour; the concentration of the vapor in the air was such that 0.4 cc. of ethylene dibromide was actually inhaled. Death resulted in 6 to 18 hours. Application of 0.25 cc. of ethylene dibromide gradually to an area of skin 2 centimeters square on the abdomen of rats likewise produced death in 6 to 18 hours. Postmortem examination of the animals, which had died from this acute poisoning, revealed a putrid, mushroom-like odor, and degenerative changes in the vascular system and the viscera, especially in the kidneys.

Ethylene dibromide had approximately the same toxicity as lead tetraethyl, but did not have a cumulative action. Ethylene dibromide is a distinct industrial health hazard, chiefly in its manufacture.

J. S. H.

Edgar Fahs Smith, Elliott Cresson Medalist in 1914, died on May 3, 1928 in the seventy-fourth year of his age. An account is given of his work, and a tribute is paid to his memory by his successor as Blanchard Professor of Chemistry in the University of Pennsylvania, WALTER T. TAGGART (*Science*, 1928, *68*, 6–8). Dr. Smith was educated at Pennsylvania College at Gettysburg, and at the University of Göttingen where he was a pupil of Wöhler. His contributions to chemistry included the determination of the atomic weight of eight elements, researches on a number of the rare elements, the complex inorganic acids, and the history of chemistry, as well as elaborate studies on the use of the electric current in quantitative chemical analysis. For these studies, he was awarded the Elliott Cresson Medal. He also held the Priestley Medal of the American Chemical Society, the Chandler Medal of Columbia University, and twenty-three honorary degrees from nineteen colleges and universities. Dr. Smith was the author and translator of numerous books and brochures in the field of chemistry. He was thirteenth Provost of the University of Pennsylvania (1911–1920) held numerous offices in learned societies, and, at various times, under the state and federal governments.

J. S. H.

Milk From Farm To Refrigerator. Under this title, the PHILADELPHIA INTER-STATE DAIRY COUNCIL has published a brochure of 6 pages describing concisely how a modern city gets its milk supply. A number of interesting facts are given. Milk is now transported from the local receiving station to the city plant in special tank

trucks or in glass-lined refrigerator cars. The plant examination includes organoleptic tests (odor and flavor), and determination of bacterial count, fat content, acidity, and sediment. The storage vats are glass-lined. Filtration is made through very fine cloth. Thorough pasteurization destroys the pathogenic bacteria which cause milk-borne diseases; it does not influence vitamins A and B, but affects vitamin C. In cooling the pasteurized milk, use is made of the principle of the countercurrent. The pipe, by which the hot milk leaves the pasteurizer, is surrounded by a larger pipe through which the cold raw milk flows to the pasteurizer. This process is completed by passage of the pasteurized milk over a mechanically refrigerated cooler. The bottles are washed and sterilized in a machine which may handle 124 bottles per minute. Another machine fills and caps more than 40 bottles per minute. The crated bottles are kept under mechanical refrigeration until placed on the delivery wagon.

J. S. H.

Free Inorganic Radicals. P. WALDEN and L. F. AUDRIETH of Cornell University (*Chem. Rev.*, 1928, *5*, 339–359) have reviewed the literature on free inorganic radicals. The term free is used of these radicals in the same sense as it is applied to certain elements like chlorine. Free chlorine is molecular chlorine Cl_2. The cyanogen radical is CN, and has a valence of 1; free cyanogen is $(CN)_2$. The halogenoid radicals which have been obtained in the free state include cyanogen $(CN)_2$, thiocyanogen $(SCN)_2$, selenocyanogen $(SeCN)_2$, oxycyanogen $(OCN)_2$, and azidocarbon disulphide $(SCSN_3)_2$. Derivatives of the halogenoid radicals are also known; they may be polymeric like ammonium trithiocyanate $NH_4(SCN)_3$, or compounds of halogenoid and halogen like cyanogen chloride CN.Cl, or compounds of the halogenoids with each other like cyanogen thiocyanate CN.SCN. Other inorganic radicals have been obtained in the free state. Thus, nitrogen peroxide, hydrogen peroxide, and hydrazine represent, respectively, two nitrite groups, two hydroxyl groups, and two amino groups joined to each other.

J. S. H.

Butter: Its Keeping and Deterioration. The factors which influence the keeping and the deterioration of butter are reviewed by OTTO RAHN of Cornell University (*Scientific M.*, 1928, *27*, 206–211). Pasteurization of the milk or cream destroys about 99.9 per cent. of the bacteria. When a starter is used to produce sour cream prior to churning, the bacteria of the starter generate lactic acid which destroys *Pseudomonas fluorescens*, a bacterium whose action on the

butter-fat gives rise to rancidity. However, certain molds, like *Oidium lactis* and *Cladosporium butyri* also produce rancidity; they grow better in the sour cream than in fresh cream. During cold storage, the bacteria, molds and yeasts present in butter decrease in number. But, if the butter be made from sour cream, a fishy flavor develops. This flavor has its origin in the decomposition of the lecithin of the butter-fat by the acid derived from the sour cream. This decomposition is greatly accelerated by the presence of metals. Butter churned from pasteurized sweet cream does not contain the acid, and consequently keeps better. While sodium chloride (salt) has a bactericidal action, it also catalyzes the decomposition of the lecithin. Unsalted butter has excellent keeping qualities provided the microörganisms which produce rancidity are absent. Butter has an extremely complicated physical structure; and this structure probably influences its keeping and deterioration.

J. S. H.

Tests for Chromium. NORMAN M. STOVER of the University of Alberta (*Jour. Am. Chem. Soc.*, 1928, *50*, 2363–2366) has compared the ether-hydrogen peroxide test and the diphenylcarbazide test for chromium with each other. The latter test was found to be far more sensitive. When a dichromate solution was acidified with sulphuric acid and shaken with ether, a positive reaction for chromium (blue color in the ether layer) was given by as little as 1 part of chromium in 1,250,000. Portions of the dichromate solution were acidified with certain acids, and a solution of diphenylcarbazide in alcohol containing 10 per cent. of acetic acid was then added; a positive reaction for chromium was the production of a color in 10 minutes; the color depended on the amount of dichromate present, being deep red with relatively large amounts and a distinct violet with small amounts. The minimum amount of chromium detected by the diphenylcarbazide was 1 part in 12,500,000 in the presence of citric acid, 1 part in over 71,000,000 in the presence of acetic acid, and 1 part in 100,000,000 or even 250,000,000 in the presence of sulphuric acid.

However, when these tests were applied in the usual course of qualitative analysis, the minimum amount of chromium detected by the diphenylcarbazide was approximately 1 part in 1,000,000 in the presence of acetic acid, while the ether-hydrogen peroxide test failed to show the presence of 1 part in 250,000.

J. S. H.

Determination of Potassium as its Iodoplatinate. ALFRED T. SHOHL and HELEN B. BENNETT of Yale University (*Jour. Biol.*

Chem., 1928, *78*, 643–651) recommend the quantitative determination of potassium as its iodoplatinate, either by titration or colorimetrically. Potassium chloroplatinate is precipitated. This precipitate is converted into potassium iodoplatinate by treatment with potassium iodide. The aqueous solution of potassium iodoplatinate has a deep wine-red color.

In the colorimetric method, the color of the unknown is compared with that of a standard. This method may be used when less than 1.6 milligrams of potassium are present in 100 cc. of solution. If the concentration of potassium exceeds this value, the solution must be diluted before comparison of the colors. The maximum error of this method is 4 per cent. of the potassium present.

In the volumetric or titration method, the potassium iodoplatinate is titrated with 0.01 normal sodium thiosulphate solution, using a micro burette calibrated to 0.01 cc. The end point is the transition to a lemon-yellow color, which is probably due to the formation of potassium iodoplatinite. The reaction supplies its own indicator. This method is convenient for amounts of potassium ranging from 0.4 to 1.0 milligram with a maximum error of 2 per cent. of the potassium.

The two procedures may be combined. The titration is made. The reduced lemon-yellow salt is oxidized to the red salt by means of hydrogen peroxide and hydrochloric acid; and the colorimetric determination is then carried out. Salts of iron and copper, ferricyanides, alcohol, exposure to brilliant sunlight, and excessive acidity are disturbing factors.

J. S. H.

New Test for Industrial Lead Poisoning. CAREY P. MCCORD (*Bull. U. S. Bureau of Labor Statistics* No. 460, 1–33, 1928) has devised a new test for industrial lead poisoning. The human blood normally contains 4,500,000 or 5,000,000 erythrocytes or red blood cells per cubic millimeter. Immature or basophilic red cells do not usually exceed 1,000 per cubic millimeter of blood; they are designated basophilic since they contain granules which are stained selectively by certain dyes like methylene blue and brilliant cresyl blue. In 145 normal adults, the number of basophilic red cells per cubic millimeter of blood was usually less than 1,000, and never exceeded 5,000. The number of these cells may be increased in certain physiological and pathological states. The entire research included the examination of the blood of 1,045 persons, of whom 550 were exposed to lead, and 50 were cases of clinical lead poisoning.

In the absence of other conditions characterized by a high basophilic red cell count, such a count indicates either lead ab-

sorption or lead poisoning in a worker exposed to lead. A progressive increase in this count in such a worker indicates imminent clinical lead poisoning. In frank cases of lead poisoning, this count usually ranges between 7,000 and 50,000, and rarely exceeds 100,000.

The high count decreases to a normal value with the excretion of the lead under treatment. When this count reaches 6,000 or 7,000 in a worker exposed to lead, especially if the increase be progressive, treatment for lead poisoning should be considered.

This test may be used to determine the degree of lead hazard in various departments of a plant or industry. It has demonstrated that many workers commonly regarded as unexposed, such as clerks and office workers, may absorb much lead and become potential cases of lead poisoning. This is especially true when the lead derivative is in the form of a dust.

J. S. H.

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